REPORTS
ON THE ECONOMIC GEOLOGY OF
THE PORBANDAR STATE

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ECONOMIC GEOLOGY OF THE PORBANDAR STATE

In the Province of Kathiawar, India

BY
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With 70 *Plates and* 15 *Coloured Geological Maps*

ISSUED UNDER THE AUTHORITY OF
MAJOR E. O'BRIEN
ADMINISTRATOR OF THE PORBANDAR STATE

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INTRODUCTION

At the instance of the late Major F. de B. Hancock, then Administrator, I was, on the 10th June, 1915, entrusted with the work of making a geological reconnaissance of the Porbandar State, with a view to the future development of its mineral and stone resources.

Every facility for travelling and for the collection of specimens and their subsequent examination was accorded ; while a workshop, laboratory and photographic studio were duly installed and equipped to my entire satisfaction ; but, for the lack of suitably trained assistants, I was obliged to do the whole of the work single-handed, with only such help as could be given by a mechanic, a stone-mason and the occasional services of the local photographer.

Instructions were issued for the preparation of a 'Rough Monthly Report' and an additional 'Quarterly Summary of Results' ; and it was at first intended that the latter alone should be printed and published, at a nominal charge, for broadcast distribution ; but, after carefully perusing a few of the monthly reports, Major Hancock, himself a well-read geologist, decided that these also should be printed and issued as an appendix to the entire work when completed. At my suggestion, however, the 'Rough Monthly Reports' were revised and incorporated in form of a 'Narrative Report' to precede the pages of the 'Quarterly Summary of Results.'

By reason of illness, Major Hancock found it advisable to take a voyage to England ; but, to the regret of everyone concerned, he died during the journey home, on 6th May, 1916 ; his duties being left in charge of Major E. O'Brien, on the 1st May, 1916, who now continues as Administrator of the State.

Reconnaissance work consisted in the selection and installation of suitable centres of observation called 'Camp-Stations,' from which excursions were made so as to cover the entire countryside in their neighbourhoods ; and, in this way, almost every inch of ground in the State was traversed and exhaustively examined. During each excursion, copious notes were taken, and specimens secured of

everything likely to be of economic worth or scientific interest, while large samples of merchantable materials, suitable for being trimmed and displayed, were also collected. All specimens were registered, accurately localised and provisionally named on a list, which will be found recorded by instalments in their proper places in the pages of the 'Narrative Report'; and, it may be casually noted that the whole of this work, even down to the labelling and packing of samples had to be done personally by myself in order to avoid mistakes. In addition to this, the field-work included the taking of a complete series of chips, some of them in definite directions, or of suitable samples for subsequent microscopical determinations or chemical analyses.

Meanwhile, specimens and samples were sent at intervals from the camp-stations to headquarters at Porbandar City, and the work of preparatory or rough grinding of the rock chips, on a lapidary-machine was carried out by the previously trained mechanic; but the delicate work of final reduction of the thin sections and their preparation as microscopical slides proved to be beyond the powers of the skilled mechanic and had also to be personally done by myself, after completion of the field work.

Upon my return to headquarters on the 17th May, 1916, the laboratory and photographic studio were overhauled and put into perfect working order; while several thin sections of each chosen specimen were prepared and typical portions marked for photo-micrographs. The 'Duplex Photo-micrographic Camera,'—specially made by the celebrated firm of MESSRS. WATSON AND SONS, LIMITED, of 313, High Holborn, London, W. C.,—and diffused day-light alone, without any accessory illuminating apparatus, was used for this work with the happiest of results. Each object having been adjusted to exhibit the required field-of-view, and personally examined and approved of, a 'half-plate' picture was then taken, developed and printed by the local photographer,—MR. JIVANDAS DAMODAS,—from which reproductions by the half-tone process were made by *The Times Press* of Bombay.

As the time allotted for the completion of the work within the period of twelve months, was found to be insufficient for further desirable laboratory research, extensions of time were granted,—

first, by the late MAJOR HANCOCK and afterwards by the present Administrator, MAJOR E. O'BRIEN,—up to the end of November, 1916. The preparation of numerous thin sections, their examination and determination of constituents under the microscope, the passing of 'proofs' for press and the compilation of an exhaustive index, proved to be a far more arduous task than anticipated; so that I found it necessary to devote the best part of my time and attention,—out of office,—to the completion of the work, up to the end of June, 1917.

My thanks are due to MESSRS. R. SYDNEY SYMONS and R. E. J. M'CULLY for their courtesy in supplying quantitative chemical analyses of a few typical samples, which will be found duly acknowledged in the pages of these reports.

It may be specially noted, that the list of registered samples, presented in the 'Narrative Report'* was submitted as merely *provisional*; but this has to some extent been rectified by the petrographical determinations given at the close of the 'Final Quarterly Report.'† The only correction of importance thereby revealed, is, that the Dhának Dhár rock, No. 91, described as a 'blue-black basalt,' turns out to be of undoubted hypabyssal and not of volcanic origin.‡

These reports ought to be frequently consulted by engineers, architects, builders, contractors and stone merchants in India, as a trustworthy guide to the choice of an entirely new, vast and varied series of both building and ornamental stones, well-calculated to supply long sought-for wants; and special attention may therefore be directed to the information given concerning the incomparably strong and durable granophyres and felsites, the hitherto unutilised rhyolites and goodly range of ornamental igneous as well as sedimentary stones, a few of which, notably the orbicular granophyre and the newly-named 'Bharwaralite' and 'Tukralite' are probably unique of their kind. The petrographical determinations, now so generally demanded by advanced architects, ought also to furnish instructive pabulum for University and other students of applied

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* *Postea*, 'Narrative Report,' p. ii.

† *Postea*, 'Final Quarterly Report, p. 90, *et sequentes*.

‡ *Postea*, 'Final Quarterly Report, p. 96.

geology ; while the practical notes and suggestions, by the way, such as the need for a Railway Station or loading platform at Bordi* ; calls for irrigation improvements † and the reclamation of vast tracts of fertile land, ‡ if adopted, could scarcely fail to lead directly to a substantial increase of revenue.

Finally, it is worthy of record, that the collection of specimens has been deposited in cabinets and shelves in the Victoria Jubilee Commemoration Hall, Porbandar, to form, it is hoped, the nucleus of a thoroughly representative State Museum.

PORBANDAR
KATHIAWAR, INDIA
August 1917

E. HOWARD ADYE
Consulting Geologist.

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* *Postea*, 'Narrative Report,' p. clxxx.

† *Postea*, 'Narrative Report.' pp. clxxii, clxxiv—clxxvii.

‡ *Postea*. Quarterly Reports,' pp. 73. 74.

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NARRATIVE REPORT

ON

THE ECONOMIC GEOLOGY OF PORBANDAR STATE

BY

E. HOWARD ADYE, F.G.S., etc.

DIGEST OF DIARY.

June, 1915.

UNDER THE VIGOROUS administration of MAJOR F. DE B. HANCOCK, a new departure has just been taken by the creation of a Geological Survey Department, under the control of MR. E. HOWARD ADYE, Consulting Geologist, London, W., and late Director of the Geological Survey of Navánagar State.

Preliminary work was commenced, when MR. ADYE took charge of his departmental duties on 10th June, 1915.

During the intervening days, from the 10th to the 26th of June 1915, the head-quarters of the Geological Survey (favourably situated at the south-eastern outskirts of the City of Porbandar) were put into good working order, and the permanent staff called together and individually instructed concerning their future duties in the ménage of the establishment.

Camp-Station I.—Head-Quarters, Porbandar City.

ON THE 23 JUNE, 1915, preparations were made for field-work and tents were pitched and arranged in the compound of the headquarters in order to drill the staff for Camp duties.

The megascopic examination of specimens, coupled with sundry physical tests, can, of course, be accomplished, under ordinary circumstances, without any drawback; but, it must be borne in mind, that on account of the "personal equation," errors in the determination of

the mineral constituents or other (organic) units of the rock-mass under consideration, are liable to occur frequently, even in the hands and under the vision of an expert. Megascopic determinations must therefore be taken as provisional, and, as such, will be entered, from time to time in the register of samples collected, until corrections can be made under the light shed by subsequent laboratory research.

Under this reservation, the subjoined list of samples is now submitted.

Date.	Regis-tered No.	Provisional Name.	Locality and Remarks.
26-6-15.	1	Rubbly, very Sandy and Ferruginous-Limestone.	Arabian sea-shore, covered by tides ½m. due E. of Headquarters.
26-6-15.	2	Shell-Sand, medium grained, probably Foraminiferal.	Low dunes, for about $\frac{1}{10}$th mile inland, overlapping No. 1.
26-6-15.	3	Same formation as No. 1, but additionally compacted by incoherent sand and ferruginous, calcareous, infiltrated earth.	Base of open pit-quarry, just NNW. of Lal Bungalow, and about $\frac{1}{10}$th mile inland, from sea-shore.
26-6-15.	4	Honeycombed, Ferruginous and Sandy-Limestone.	Overlying No. 3 to a maximum thickness of nearly 10 ft.
26-6-15.	5	Consolidated Shell-Sand, compact, hard, whitish-grey, sound stone. Suitable for break-waters.	Broken boulders, *in situ*, at high-tide mark. 1¼ m. SSE. of Head-quarters and near Palace.
26-6-15.	6	Grey-brown. Honeycombed and Appreciably Sandy-Limestone. Has been used, and is a good strong 3rd grade building-stone when faced with plaster.	Small pit-quarry (abandoned), called Khetlia Khán. Quarried nearly 40 ft. Water-logged during monsoon. Well-shaft at bottom, now shows underground water-level, 23 ft. from surface.

It may be remarked, that the above-noted registered specimens have been collected in sound pieces of irregular sizes, technically termed 'hand-samples'. When, however, minerals and rocks of special interest or economic worth are discovered, additional specimens of suitable sizes will be collected, trimmed and otherwise manipulated to display their intrinsic merits to the best advantage, and deposited along with detailed notes for the information and guidance of commercial men, contractors and consumers, in exhibition-cases now being designed and constructed for their reception.

DIGEST OF DIARY.

July, 1915.

PORBANDAR CITY including its immediate outskirts, is apparently built upon a comparatively recent substratum of consolidated shell-sand, partly of æolian origin, but mainly of the nature of a raised-beach. This geological deduction is based upon premises, derived from careful observations of exposures along the sea-shore extending from the harbour in a south-easterly direction to a little beyond the Palace demesne; and inland, covering the area included between the sub-triangular boundaries afforded by the highways from Porbandar to Ránáwáo, to Ádatiána, and from thence, *viâ* the villages of Kolikhara and Khápat, back to the City. The inland evidences of geological structure, were gathered by an examination of superficial inequalities, the scarps of streams and other water courses, well-shafts and sundry minor excavations.

It was found that the consolidated shell-sand, constituted by stone of both sub-aerial and littoral-marine origin, extends interruptedly,—by reason of variations in denudation from place to place,—right away to the uplands verging upon the great miliolite-limestone series of marine deposits; and that both the sub-recent shell-sand which overlaps the older (probably Pleistocene) miliolite and the later, in this region of the province, rest upon the fossiliferous limonitic or Gáj limestones of Tertiary age.

Evidence in support of the above-noted observations is to be found. by an examination of hand-specimens of the compactly consolidated shell-sand, which fringes the shore-line from Porbandar City in a south-eastward direction to be exceptionally well demonstrated by the huge breakers and lower-lying unbroken beds on the coast-line below the purlieus of the Ráná Saheb's Palace. These solid pieces of stone contain unmistakable pebbles and angular fragments of Tertiary (Gáj), limonitic-limestone with their characteristic fossil remains.

Again, on the NE. bank of the city-encircling Creek, after crossing the bridge that spans that conduit, on the Ránáwáo Road, an excellent exposure is shown displaying rough, rubbly beds of either consolidated shell-sand or of broken miliolite, resting directly upon the yellow limonitic-limestone of Tertiary age. Skirting the Creek from this part, in a NNW. direction a small stream or *nala*, has been effectual in eroding the superficial beds, and bending southward reveals at the site of aban-

doned chunam-pits, a remnant of rough miliolite lying upon rubbly and then upon solid beds of fossiliferous Gáj limestone. The Gáj limestone, moreover, is again revealed by the E. scarp of a rivulet, the Wandána Vokala, adjoining the village of Virpur, about 5½ miles eastward of Porbandar on the road to Ránáwáo. Before reaching Virpur, however, the somewhat doubtful character of the rubbly surface-stone which is seemingly co-extensive with the hard siliceo-calcareous shell-sand, outcropping by the Ráná Saheb's Palace and forming a rock-plain in continuity with the stone of the entire countryside surrounding the Ránáwáo Road towards the limits of Virpur, the ground has been pierced by a few well-shafts, and notably by a shallow excavation about one mile SSW. of Virpur, which shows the whitish-limestone or shell-sand tailing down, to just barely conceal a thick, 4 to 6 feet, stratum of brecciated conglomerate with indications of underlying Gáj limestone deposits.

The observations recorded above were duly noted in the writer's field-book on the 9th of July, 1915, during the traverse from Camp-Station I, at Head-quarters, to Camp-Station II, where tents were pitched on the SW. outskirts of the town of Ránáwáo; and the following samples were secured, registered and packed for future investigation in the laboratory:—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
5-7-15.	7	Consolidated Shell-Sand. Medium-textured, very compact strong stone, with traces of Gaj Limestone pebbles, etc.	Exposed by receding tide, just below high-water mark, as a fringe of broken beds, below Customs House, Porbandar.
5-7-15.	8	Sample of Road-Metal being used by Contractors for Porbandar Roadways.	From Contractor's heaps, on the Rajmahal Road, near the Library. For testing.
5-7-15.	9	Consolidating Shell-Sand. Of fine texture, showing incipient induration.	Base of 10 ft. Pit through Dunes 150 yds. from low-tide mark, nearly opposite Hospital.
5-7-15.	10	Consolidated Shell-Sand. Jagged surface, containing shells of recent *Mollusca*, etc.	Sub-recent formation at low-water mark. Opposite Hospital.
5-7-15.	11	Consolidated Shell-Sand. Smooth surfaced beds, was formerly quarried superficially.	At extreme edge of low-tide in continuation seawards of No. 10.

Date	Registered No.	Provisional Name.	Locality and Remarks.
5-7-15.	12	Consolidated Shell-Sand. Containing fossils and fragments of Gáj Limonitic Limestone.	Same site as No. 5.
5-7-15.	13	Rubbly-Rock forming bulk of Earthy, Calcareous Conglomerate of Shell-Sand beds of Sub-recent formation.	Surface of Roadside a little beyond the Ráná Saheb's Palace. Exposed thus almost everywhere around, and now being used for road-metal.
6-7-15.	14	Consolidated Shell-Sand. Jagged surface but in solid beds 1 to 2 ft. thick below, overlying 6 to 12 ins. of yellowish limy Conglomerate with Gáj fragments.	W. bank of Creek spanned by Bridge of Ránáwao Road, 1½ miles NE. of Headquarters of Geological Survey, Porbandar.
6-7-15.	15	Limonitic-Limestone. Gáj Group. Only 2 ft. exposed underlying conglomerate of No. 14.	Same site as No. 14.
6-7-15.	16	Consolidated Shell-Sand. 2 ft. thick, very hard surface beds, overlying earthy and limy conglomerate containing Gáj limestone pebbles and fragments.	NE. bank of Creek, at other end of Bridge. *Vide* No. 14.
6-7-15.	17	Rubbly. Pink-yellow, finely-textured stone, top surface of Gáj Limestone. The surroundings are overlaid by rough shell-sand rock or sandy-miliolite.	1¾ miles NE. of Geological Survey Bungalow. Exposed by scarp of meandering stream which swerves S. and then E. to scarp of former chunam-pit.
6-7-15.	18	Highly Fossiliferous. Gáj. Limonitic Limestone.	Immediately underlying No. 17, in 1 ft. thick beds.
9-7-15.	19	Consolidated Shell-Sand, merging into Gáj, Limonitic-Limestone. Is practically a Rubbly, Earthy, Limy, Brecciated Conglomerate.	½ mile from Bridged-Creek on Highway to Ranáwáo. Is being used for repairing roads.
9-7-15.	20	Consolidated Shell-Sand (?) Large slabs 4 to 12 inches thick. Dips at angle of 20°, 30°-35°.	Rock-Plain, 4 miles from Porbandar, surrounding the Highway to Ránáwáo.
9-7-15.	21	Stones from Brecciated Conglomerate, underlying superficial bed of Shell-Sand Rock. Excavated 3-5 feet.	Same rock-plain as No. 20. The Shell-Sand tails down here to *nil*. The Conglomerate is limonitic, probably overlying Gáj.
9-7-15.	22	White-Stone, partly honeycombed, Thick blocks, bedded to unknown depth.	By roadside well-shaft, 5 miles from Porbandar on highway to Ránáwáo.

Date.	Regis-tered No.	Provisional Name.	Locality and Remarks.
9-7-15.	23	Brecciated-Conglomerate, holding mainly fragments of Shell-Sand from thin layer above, and of Gáj Limonitic Limestone from below.	Exposed by E. scarp of the Wan-dána Vokala at Virpur village on S. side of highway 4 miles SW. of Ranáwáo.
9-7-15.	24	Gáj, Limonitic-Limestone ..	Immediately underlying No. 23.
9-7-15.	25	Sound Rough-textured Stone ..	Outskirts. ½ mile from town of Ránáwáo on SW. side.

Among the strictly so-called economic stones, noted in the foregoing list, precedence must unquestionably be accorded to the Consolidated Shell-Sand, and especially to those varieties of the texture that are available in closely compacted form capable of being extracted in large and average-sized blocks for building purposes. Unfortunately however, within the limits of the traverse already accomplished, such stones are only exposed along the coast ; while, if quarried for inland, no bright prospects can be offered in the face of the fact that even if obtainable, pit-quarries on level-land are liable to be water-logged, and the probable sites are nearly all required for building purposes. Other sites may nevertheless be yet discovered ; and, in anticipation it may be recorded that the stone is so indurated as to be polishable ; and is so strong and tough that it can be utilised for situations subjected to hard wear and tear, especially in the vicinity of the sea-side,—as salt spray appears to have little or no effect in the weathering and wearing-down of the rock-mass.

Camp-Station II.—Ranawao ; SW. Outskirts.

On the morning of 10th July, 1915, arrangements were made for a first visit to the site of the extensive miliolite-limestone quarries for which Porbandar State has for many years been so famous. A keen outlook was kept in covering the ground from its lower levels at the town of Ránáwáo up to the heights of Ádatiána, (where the vast series of excavations is situated in the deep south-western cradle at the base of the Barda group of hills), in order to ascertain, if possible, the true relations of the local geological formations.

Ránáwáo town stands about 80 feet above the mean sea-level, and from thence there is a gradual rise of the surface to 260 feet at Ránáwáo Railway Station. This short traverse of a trifle less than 2 miles, shows, at Ránáwáo, an exposure of beds of medium textured, light buff coloured miliolite-limestone ; but, about midway on the road to the Station, a small stream is encountered, which reveals, by its eroded channel, the undernoted interesting evidence, which may or may not go to prove that the raised-beach, *en évidence*, at Porbandar, reaches as far inland as this spot. It all depends upon whether the surface stone turns out to be a consolidated shell-sand when examined under the microscope. It would be premature in this place to enter into a detailed explanation of the differences which obtain between consolidated shell-sands and true miliolite-limestones ; but it may here be stated, to be verified hereafter, that these differences can be unerringly demonstrated by a mere glance through thin sections of the respective specimens.

From Ránáwáo Station, the quarry-trolly was taken along the Railway-siding up an incline from the 260 feet level, up to the quarry-sites at about 296 feet above the level of the sea. *En route*, several stoppages were made for the purpose of making field-notes and taking samples ;—principally, as follows :—

About 100 yards due N. of Ránáwáo Station, the surface exposure is peculiar, in that the beds of stone are tilted or dip at an angle of about 45°, while the finely-textured stone, with a flaggy tendency, appears to be a very ferruginous miliolite of a ruddy-buff colour and liable to be much honeycombed and cancellated at places. The unusual dip of the beds is doubtless due to false-bedding.

Nearly one mile from Ránáwáo Station, alongside the Quarry Railway-Siding, the rock exposure on a level with the line, presents an aspect singularly like to that of a raised-beach, with its jagged-surface of consolidated shell-sand. Samples of these stones, were, of course, secured for laboratory examination ; while, about a quarter of a mile farther forward, the site is reached where an underground cave, called " Jambuvanti Bhoira " (after one of the wives of the mythical Krishna), is preserved as a kind of show-place. The cave-entrance is reached by a short pathway out of the beaten track and railway-siding, and leads down by a semi-spiral staircase, cut through the solid rock, for a mean depth of about 20 feet. The subterranean chambers with their passages, duly ventilated by a couple of vertical shafts, was, without doubt, a natural formation, subsequently elaborated by man. Its

geological structure shows a series of obliquely laminated beds of coarse, sandy, buff-coloured miliolite-limestone of but small commercial value, of a total thickness of from 20 to 25 feet, deposited directly upon a fairly thick substratum of brown, earthy, ferruginous incoherent sand full of glittering particles. The cave itself must have taken origin through the accumulation of underground waters and subsequent formation of a subterranean stream, which effectually swept away the rubbly layers of stone and also a considerable portion of the underlying decomposed sand, the precise nature of which remains to be revealed by analysis in the laboratory.

By far the most valuable asset in economic stone, at this far-famed site, comes the series of miliolite-limestones, in deep deposits along the mighty trough at the base of the lofty hills, which form the SW. limitation of the Barda group of hypabyssal intrusions, now laid bare by denudation. The miliolite itself, which like all true sedimentary deposits, occurs in great lenticular beds, varies considerably in total thickness from place to place, according to the inequalities of the base of the basin upon which it was successively deposited. It also naturally varies in quality, both vertically and horizontally, and consequently furnishes a very wide range of samples, differing from each other in texture, colour, and quantitative composition of its clastic units ; so that a correspondingly large number of grades of merchantable stone is available.

Arrangements were therefore made with the quarries-clerk, to get the several contractors to send sample-blocks, vernacular trade names, prices current and general information incidental to the subject to the headquarters of the Geological Survey at Porbandar. From these specimens and data, it is hoped that a very complete detailed commercial, coupled with a scientific report may shortly be forthcoming.

It may be noted, *en passant*, that from the meagre coarse deposits of miliolite at the 260 feet level of Ránáwáo Station, up to the end of the main Railway-siding, which rises to a maximum level of 296 feet above datum, there are no less than 72 loading-platforms, and a succession of 292 quarries, of which 174 are now in active operation. It may also be recorded, that there is a well-shaft, at the commencement of the great quarry range, which has been sunk to a depth of about 80 feet, through beds of miliolite, down to the water-level underground, which has been conserved at that depth by the practically impervious granophyre below.

Evidences are not wanting to show that the vast miliolite deposits of the Ádatiána heights, are sub-marine in origin, and that they must

have accumulated during Post-Tertiary times, to leave their limit-mark in this locality, at about 300 feet above the level of the sea. Facts and figures in corroboration of this statement, will be forthcoming in the sequel.

Flanking the main quarry-range from SE. to NW. on its south-eastern aspect, there is a lofty ridge of huge hills, rising in altitude from 765 feet at its south-eastern to 1,077 feet at its north-western end. These hills give forth spurs in various directions; but agree, in being supplemented towards their bases by more or less parallel eminences or nether ridges; *and it is to these nether ridges, made easily accessible by the great quarry Railway-siding, that extra-special attention is most worthy of being directed.*

Although the high hills themselves would, without doubt, yield an almost inexhaustible supply of very useful and valuable building-stone in great variety, the capital required for the exploitation of mines and quarries, would, at the present juncture, be entirely, "out of the question." The nether hills on the contrary, not only lie within a reasonable distance of the existing railway-siding, but frequently encroach upon the line itself; and, what is of most importance, are capable of yielding practically unlimited supplies of precisely those varieties of stone that have for many years past been clamoured for in vain, by progressive engineers, architects and builders in India. *These desirable commodities are comprised by a truly magnificent series of perhaps the toughest and strongest of rocks in existence*, and embrace examples of granophyric textures, in variety and value, even superior to the granite-porphyries, porphyrites and granophyres of the celebrated Charnwood Forest in England, which have long held a premier position in the stone-markets of the world by reason of their exceptional strength and durability and suitability for dock and harbour construction, embankments, road-engineering operations, and indeed for all purposes where resistance to both dry and wet attrition and the stress incidental to perpetual hèavy-traffic, is considered to be a *sine quâ non.*

Over and above the pronounced physical properties and manifold special applications enumerated above, a few of the granophyres of the "Ránáwáo Range," as it may appropriately be named, *justify a claim to rank high in the scale of ornamental stones*, and are procurable in quantities and sizes to meet all known requirements, from the fashioning of polished columns, pedestals and monuments, to the manufacture of mantel-shelves, table-tops, clock-cases and the like.

Additional information may be gathered from the subjoined list of samples collected for laboratory investigations and future reference, during the surveys of 10th and 13th July, 1915 :—

Date.	Regis-tered No.	Provisional Name.	Locality and Remarks.
10-7-15.	26	Consolidated Shell-Sand (?). Denuded to 6-12 ins. Underlying this is 6 in. to 3 ft. Earthy-Conglomerate.	Railway Road, Ránawao, 1 mile SE. from Station Scarp of stream under small bridge.
10-7-15.	27	Coarse Miliolite-Limestone. In beds 2 to 8 ins. thick, below the overlapping conglomerate.	Same site as No. 26. The earthy limy conglomerate is brecciated with large fragments of limestone.
10-7-15.	28	Ruddy-buff, hard Miliolite. Tilted at of 45°.	100 yards due N. of Ranawao Railway-Station. Very ferruginous.
10-7-15.	29	Jagged-topped sandy Limestone.	Nearly 1 mile NWW. by NW of Ranáwáo Railway-Station, by side of Railway siding to the Great Quarries.
10-7-13.	30	Sand of Decayed Granophyre from bottom of Cave, 25 ft. from surface. Cave is called "Jambuvanti Bhoira," after one of Krishna's wives.	1¼ miles NW of Ranawao Railway Station. Formerly occupied by an ascetic
10-7-15.	31	Sand and Bottom-Stone of Roof of Nether Cave.	Same site as No. 30.
10-7-15.	32	Top-Beds of Cave	Surface stone. Same site as No 30.
10-7-15.	33	Grey Granophyre. Medium porphyritic, very tough, but is slightly weathered superficially.	100 yards E. of Rail-line, at "Navri Quarry," No. 62, at about level of limestone limit on ridge called Khoria Dhár.
10-7-15.	34	Dark-Grey Spherulitic. Granophyre. Very tough, in subsoil boulders, slightly weathered.	Same locality as No. 33, but quite close up to and for 50 yds. ENE. of the Railway-siding.
10-7-15.	35	Highest-Grade Miliolite. 25 ft. from surface and a little higher up.	Towards base of Quarry No. 50, Ránáwáo Range. Enormous sound blocks are available.
10-7-15.	36	Light-buff, High-grade Miliolite. Second only to No. 35.	Same site, "Nevri Wali" Quarry, but towards surface of No. 35.
10-7-15.	37	Rough-Miliolite, not used. Indurated, but fissile and buff.	Base of Quarry No. 50, about 28 feet from surface.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
10-7-15.	38	Porphyritic Ruddy-Grey Granophyre. Large tolerably fresh boulders in subsoil. Ought to yield handsome very tough stone if blasted. Ruddy part is probably only superficial.	Mohr Chupra Dhár, the nether hill of Mohr Chupra Dungar. Porbandar Cement Works use a long cart-track to this site. Ruddy colour probably due to sun-baking and monsoon conditions.
13-7-15.	39	Pink and Black-Grey Granitoid Granophyre. Very ornamental stone.	Under Rail-line and ENE. adjoining in large boulders of sub-soil, at Quarry No. 158.
13-7-15.	40	Miliolite-Limestone. Medium to coarse grained, light-buff. 2nd grade stone for ordinary building blocks.	Ránáwao-Range. Quarry No. 15. Commercially called "Nasakia," in vernacular, by the quarrymen and contractors.
13-7-15.	41	Miliolite-Limestone. Light-buff, medium, 2 inch slabs.	Ránáwao Range. Quarry No. 46. Slabs are called "Chorsi."
13-7-15.	42	Miliolite-Limestone. Buff-grey. Fine—grained, hard, useful building-stone.	Ranáwao Range Quarry. So-called "Yellow-stone," from Quarry No. 167.

On the 14th July, 1915, it was found desirable for their safe preservation to convey the samples collected to head-quarters at Porbandar and at the same time to cover new ground by making a geological reconnaissance of the sub-triangular strip of countryside bounded by the Ránáwáo to Porbandar high-road on the south, the cart-road from Ránáwáo to the village of Ádatiána in a north-westward direction, and from thence, along the made-road running from Ádatiána, *viâ* Kolikhara and Khápat to the Capital City.

It was noted that the surface deposits of miliolite on the comparatively low-lying plain,—80 to 100 feet above the sea-level, in proceeding from Ránáwáo to Ádatiána, consists of thin beds and rubbly layers of miliolite of very indifferent quality, occasionally developed to a sufficient degree to tempt quarrying operations to supply local wants. On approaching Ádatiána to within 500 yards from the SE., a small excavation revealed the presence of from 6 to 8 inches of a honeycombed, indurated and finely textured miliolite, overlying about 3 feet of very ferruginous rubbly and earthly, limy conglomerate;—of both of which samples were taken. The made-road from Ádatiána to Porbandar was under repairs;—

the "metal" used being collected haphazard from the surrounding plains, of the nature of indurated and sandy limestone, which furnishes a good, smooth but fugacious surface. The countryside, with its frequent exposures of more or less of this hardened limestone, is rescued from utter sterility by fertile alluvium of a calcareous character indued with a proportion of sand and clay, washed down from the neighbouring uplands of miliolite and the hills of hypabyssal rocks that tower aloft.

Close by Kolikhara, the nature of the surface varies slightly, as thown by a recently-sunk well-shaft in a field about 500 yards NE. of he village, which reveals, from above downwards, from 1 to 2 feet of grey alluvial detritus, covering thin beds of broken, coarse limestone which merges into fully ten feet, (the depth of the water-level), of a rubbly yellow conglomerate, full of deep red-brown pebbles of probably Tertiary limonitic limestone.

Samples secured during this journey are as follows :—

Date.	Registered No.	Provisional Name	Locality and Remarks.
14-7-15.	43	Coarse, Sandy, Buff-brown, Hard Limestone.	6 to 8 ins. surface-stone overlying No. 44.
14-7-15.	44	Rubby, Calcareous, Earthy Conglomerate. About 3 ft. thick.	Roadside, 500 yds. SE. of Ádatiána, underlying No. 43.
14-7-15.	45	Rubbly, Yellow Conglomerate with Red-Brown pebbles, probably Gáj.	3 to 10 ft. below surface. New well-shaft in field, 500 yds. N E. of Kolikhara.

The proper bestowal of specimens, supervision of the work of the mechanic and business duties of the Clerk at the Hazur Office, necessitated the stay at head-quarters for two days only ; so that on the morning of 15th July, 1915, the return journey to Camp-Station II, at Ránáwáo was made as expeditiously as possible.

On 17th July, 1915, an endeavour was made to examine the geological structure of the hitherto untraversed tract of territory lying to the immediate N. and NE. of Ránáwáo, up to the southern flanks of the Barda group of hills, but although desirable, on account of the presence of cuttings and other exposures on and in the neighbourhood of the Railway-line, for about a couple of miles north-eastward from Ránáwáo Station, it was found impracticable, by reason of the rough character of the country side and the absence of other than agricultural cart-tracks to examine, at least, for the time being, the structure of the area of

about two square miles, lying approximately to the north of Ránáwáo town.

A few of the NW. to SE. spurs from the adjacent hills, cut across or abut upon the Railway-line, and sometimes outcrop as outliers to the south beyond, and these may be presumed to yield easily accessible and favourably situated material of economic importance. In the meantime, the exceedingly rough cart-tract leading over a surface of broken beds of miliolite, from the east side of Ránáwáo town, and trending NE. towards the Railway-line and thence to the village of Bordi or Sultanpur, was followed for about 1$\frac{4}{5}$ths miles; to a thickening, in ridge-like form, of the hard, sandy, buff-coloured miliolite, which is largely quarried intermittently for nearly a mile running from SW. to NE., under distinctive native names, the most noteworthy of which are the "Boda Talav Khán," and the "Goani Khán," both of which are concerned in supplying strong second and third-grade stone, chiefly in building-blocks for local consumption.

Progressing on foot farther forward, but out of the beaten track over fields and rock-wastes, in a NNE. direction towards the Railway line, a series of mounds constituted by great boulders, and more or less surrounded by thin deposits of miliolite, (thereby giving them the character of outliers), was discovered to disclose the presence of many varieties of sound and strong granophyres of economic worth, some of which exhibit a basaltoid aspect. Samples of types of these were taken and listed as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
17-7-15.	46	Coarse, Sandy, Buff, Hard Miliolite-Limestone, much honeycombed above; but compact at base. A strong, useful 2nd to 3rd grade building-stone.	About 1$\frac{1}{2}$m. NE. of Ránáwáo called "Boda Talav Khan." Runs SW. to NE. for a mile or so, and then quarry is named "Goani Khán," 6-15 ft. deep.
17-7-15.	47	Light Blue-grey Rock. Only superficially weathered. From fresh block at bottom of mound.	Mound outcrop of Dyke. About 100 yds. oval-area. 2$\frac{3}{4}$ m. NE. of Ránáwáo. Nearly 1 m. S. of Railway-line.
17-7-15.	48	Ruddy Blue-Grey Rock. Indurated by sun-baking.	Same stone as No. 47, but from side of top of mound.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
17-7-15.	49	Light Blue-Grey Rock. Fresh sample.	2¼ m. ENE. of Ránáwáo Station. 2nd Mound, nearer Rail-line.
17-7-15	50	Coarse, Grey Granophyre with yellow-green alteration-products. In huge denuded surface boulders; but very tough.	Adjoining NW. base of No. 49. Is one of many small outlying exposures in this place south of the Railway-line.
17-7-15.	51	Light-grey Granophyre of fine texture, fresh and unaltered.	Small outlier adjoining No. 50, but a little closer to the Railway-line.
17-7-15.	52	Dark, Dyke Rock. Very wide and laterally compressed, so as to be cleaved. Laterised by monsoon conditions.	Cuts through the Granophyre Outliers Nos. 50 and 51, and also through the dyke-hillock No. 54.
17-7-15.	53	Cleaved Dyke. Partially altered.	Same as No. 52, but taken from summit of No. 54.
17-7-15.	54	Blue-Grey Granophyre. Fresh, and fine to medium.	Near Railway-line, 3 m. ENE. of Ránáwáo Station.
17-7-15.	55	Pale Blue-Grey Granophyre. Sun-baked, ruddy in patches at surface. Very good, sound stone.	Outlying outcrop of spur from Jerickhia Dungar. About 150 yds. S. of Rail-line, and 3 m. ENE. of Ránawáo Station.
17-7-15.	56	Whitish Grey-brown, slightly altered fine grained Granophyre.	Spur of Jerickhia Dungar. Nearly opposite No. 55, on N. side of Railway-line.
17-7-15.	57	Light Blue-grey Rock. Ridge from NW. to SE. marked "Naliadhár State-Jungle-Reserve," on Map.	Large, long ridge, about 3¾ m. E. of Ránáwáo Station, and ⅓ to ¾ m. S. of Railway-line called "Gurarkhi Dhár."

Observations in continuation of those made on the 17th instant were completed on the 20th July, 1915, when an excursion from Ránáwáo Camp-Station was taken due ESE., along the made-road for a distance of about two miles. It was noted that the countryside on both sides, of the highway consists essentially of a broad flat plain of superficial rubbly miliolite-limestone overlying a base of earthy and limy conglomerate and barely capable of cultivation in patches. A cart-track turning on the left-hand side, led through ploughed fields in a NNE. direction for another mile and a-half to the village of Bhod, and a sample of the soil showed signs of fertility in being composed of detrital matter

mainly calcareous but appreciably mixed with argillaceous matter and sandy particles derived from the degradation of hypabyssal rocks.

At Bhod itself, the superficial miliolite thickens and grows very rough and rutty along the cart-tracks and pathless rocky-wastes, so that it was a matter of the utmost difficulty to make one's way through the thick underscrub of stunted-babuls and the bastard-teak along an agricultural cart-way, (mostly over rugged dales and mounds of rough miliolite), which terminated abruptly by the side of a small outlying hillock of light blue-grey, finely-textured, probably granophyric rock, lying within the boundaries of the State Jungle-Reserve known as Naliádhár, about 2 miles NNW. of Bhod, and just S. of the great outlier called Dudjhara Dungar.

Proceeding eastward on foot to a spot about 2 miles N. by NNE. from Bhod, another isolated outlier trending SE., and surrounded by a fringe of rough coarse miliolite, within the region of the Naliádhár State Jungle-Reserve, and locally called Naliádhár-ka-Tobra, is found to consist of a mound of huge spheroidal boulders of a tough coarse brown-grey granophyre. The undulating southward slopes of this and of many of the neighbouring eminences, are liberally strewed with angular and sometimes rounded fragments of stone, mostly of the nature of granophyres, measuring, on an average about six inches across. When these are examined they are found to consist of tolerably fresh pieces of stone, superficially weathered to the depth of only a fraction of an inch. The coarsergrained and therefore more deeply decomposed of these lumps of stone together with the occasional and sometimes frequent fragments of miliolite with which they are generally associated, should be rejected and only the finer-grained fresh-looking pieces may be gathered and broken to from 1 to 1½ inch gauge, to yield an abundance of valuable road-metal, at a minimum of cost for labour.

Many thousands of cart-loads of this ready-made road-metal, so to speak, could be collected and conveyed to the Railway-line hard-by and entrained for experimental operations to Porbandar, at small cost; but it must be borne in mind, that this material although vastly superior in points of durability and suitability for resisting severe attrition and crushing, to anything that has hitherto been used, cannot be counted on for continuous unlimited supplies; and must necessarily fall short albeit not very far short, of fresh fragments dislocated by blasting. Then too, a constant supervision must be exercised to prevent "scamped-work" and the ignorant collection of decomposed fragments and chunks of miliolite, which would, of course, inevitably vitiate results.

The specimens gathered for future examination on 20th July, 1915, are registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
20-7-15.	58	Detrital Soil of Miliolite and some Felsitic-earth from mountain-washings, about 1 to 2 ft. deep overlying thin rubbly miliolite and the miliolite-conglomerate below it.	About ½ mile W. of Bhod. From arable ground said to be fairly fertile for cereals, but not quite so good for cotton, which, however, is also grown thereabouts.
20-7-15.	59	Light, Blue-grey Fine Textured Granophyre. Outlier of large boulders bordered by crust of miliolite.	State Jungle-Reserve called "Naliádhár," about 2 miles NW. of Bhod, and just S. of outlier called Dudjhára Dungar.
20-7-15.	60	Variety of 59	A few yards from No. 59.
20-7-15.	61	Coarse, Brown-grey Granophyre. In huge boulders of outlier fringed by beds of rubbly miliolite.	2 miles N. by NNE. of Bhod called "Naliádhár-ka-Tobra."

Having thus-far covered the ground eastward of Ránáwáo as far as Bhod, on the southern base, and also north-eastward, below the limitation of the Railway-line and including the nether half of the Naliádhár State-Jungle-reserve, it remained to transfer the camp to another centre ; and accordingly, on the 21st July, 1915, a final traverse, hereinunder noted was made from Ránáwáo to the village of Bordi ;— also called Sultánpur.

New ground was entered upon after following the north-easterly rough cart-track from Ránáwáo Town, towards Bordi, when a spur from the Barda Hills, running from NW. to SE. alongside the cart-road, was examined, and found to consist of an excellent, strong and tough, medium-textured light, grey-brown granophyre, suitable for being blasted to yield large building-blocks, and high-grade wastage for road-metalling. The huge spur lies immediately N. of the W. end of the Naliádhár State-Jungle-reserve, and less than ½ mile S. of the Railway.

Proceeding onward to Bordi, the roadway winds through a pass between the hills of the final southwardly trending large spur from the Barda group at this, its south-eastern termination. The hill to the

N. of the roadway at the pass, is locally known as Bora Dubba, and its base yields an abundance of big, fresh blocks of a pale, blue-grey, finely-textured granophyre. On the S. side of the pass, the surface of the ground bristles with big bosses of rock which form the base of the same spur in semblance of an outlier, at the NW. end of the Naliádhár State Jungle-reserve. These bosses consist of a medium-grained, light brown-grey granophyre, which, albeit, crowded with yellowish-green alteration products, is very tough and strong.

Beyond the pass the cart-road to Bordi runs NE. by ENE. close by the Railway-line, along what is called the " Javantara Gara," at the base of Piara Dungar (459 ft. above sea-level), with its curious crown of free digitoid columns pointing heavenward. The road to Bordi diverges slightly southward from the Railway-line to the same village, and almost immediately after emerging from the hill-pass on to the plain at the base of Piara Dungar and ESE. of Javantara Gara, crosses over a gentle rising of the ground, caused by the exposure of the top of a very broad dyke which is cut through by the Railway-line, and takes a course from WNW. by W. to ESE. by E. The rock of this dyke, when slightly weathered, presents a mottled appearance, in spots and patches of blue-grey and yellowish-brown. It is very hard, but somewhat splintery, and it is probable that when blasted, the fresh stone will lose its yellow brown maculation and present a deep blue-grey ground spotted with lighter patches of the same colour. The weathered surface assumes a ruddy-yellowish-brown hue, sufficiently distinct from the surrounding rocks to attract attention and mark the general course of the dyke above-ground. From observations elsewhere, this rock may be provisionally named a Sub-Spherulitic Felsite. It is capable of being highly polished, and, especially towards its weathered surface,—mottled blue-grey and yellowish-brown, furnishes material of a highly ornamental character which could advantageously be utilised by manufacturers of small stonewares, such as vases, clock-cases, ink-stands, etc., where very large and uniformly marked blocks or slabs are not required. An enormous, but scarcely measurable quantity of the material exists at the site indicated above.

Onward by the roadside, which swerves north-eastward to Bordi, the ground on either side shows outcrops of great upstanding columns and boulders—the representatives aboveground of vast granophyric subjacent structures, which stretch southward from the Barda Hills, and find expression on the south side by sundry outliers of considerable magnitude. From one of these last-named outliers which forms a

high-ridge, trending from NW. to SE. and constituting the central uplands of the Naliádhár State-Jungle-reserve, there stretches a spur of boldly upstanding bosses by the roadside 1½ miles SW. of Bordi village, the stone of which consists of a coarsish white-grey granophyre, with exceptionally bright yellowish-green alteration-products in abundance; but, in spite of which the rock-mass remains supremely strong and tough enough to resist repeated blows, on even its edges, with heavy sledge-hammers. Indeed, all of the rocks exposed upon this plain around and about the village of Bordi, are of the nature of more or less coarsely-textured granophyres of great strength and durability.

The following is a list of the samples collected during the journey from Ránáwáo to Bordi, on 21st July, 1915:—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
21-7-15	62	Grey-brown, Light-coloured medium-textured Granophyre. Sound and strong Building stone in immense quantity.	Spur from Barda Hills. 3 m NE. of Ránáwáo on road-side to Bordi. Spur runs NW. to SE. and lies just N of Naliadhár Jungle-reserve.
21-7-15	63	Pale, Blue-grey, Fine-textured, Sound, Fresh Granophyre In large Boulders and Columns	Base of hill called Bora Dubba, at road-pass to Bordi. 3½ m. NW. of Ranawao.
21-7-15	64	Medium to Coarse-textured. Ruddy, Brown-grey Granophyre with yellow-green alteration products.	Outlier, fringed at base with Rubbly-Miliolite, opposite No. 63, on its S. side, within Naliádhar.
21-7-15	65	Mottled, Pale Blue-grey and Ruddy Brown-grey, Ornamental. Surface-weathered, probably a Spherulitic, Granophyric-Felsite	Very broad Dyke, low elevation, runs NNW by W. to ESE. by E., at base of Piara Dungar called Javantára Gara. Is cut by Railway-line.
21-7-15	66	Coarse Grey Granophyre in large boulders, which would yield plenty sound stone if blasted. Is weathered, but tough.	On S of Roadside, 2 miles SW. of Bordi, and about one mile ESE. of Piara Dungar and Javantára Gará.
21-7-15	67	Coarsish White-grey Granophyre. Very tough but exhibiting bright yellow-green alteration-patches. Resembles, but is superior to the stone exposed at Tarsai in Navánagar State.	In huge bosses forming a dyke-spur from high ridge to its S., called Dudjhára Dungar and Ghojhára Dungar. 1¾ miles SW. of Bordi. About ¼ mile S. of the cart-road.

Camp-Station III.—Bordi or Sultanpur.

SW. Outskirts by Village.

ABOUT 200 YARDS S. of the village of Bordi, there is a bend of the Dhángawa Vokala, which wends its way south-eastward to join the River Minsar about a mile SSE. of Khirasra. The southern incurved bank of the stream at this part shows a small but steep scarp revealing a thin superficial crust of coarse sandy-miliolite (6 to 12 inches) overlying from 3 to 4 feet of rubbly, earthy, calcareous conglomerate, which rests upon large broken blocks and boulders of fine to medium-textured whitish-grey granophyre. Both the miliolite and its basement of conglomerate are completely denuded away from the northern bank of the stream, and the granophyre with its weathered accompaniment of felsitic sand, stretches northward to form the foundations of the village and to constitute an undulating rock-plain, diversified by numerous knolls and hillocks, right away up towards the confines of the Barda group of hills. These knolls and hillocks as well as the surface of the rock-plain, yield quite a variety of granophyres, which when blasted, as they have been, by the neighbouring Railway-line, all agree in being exceedingly tough and strong ; so resistful indeed to methods of native labour, that the big, dislocated blocks cast aside by the Railway labourers, remain to this day untouched and unutilised ; while the comparatively frail, soft, easily-broken limestone, much of it brought from far-distant sites, is being used as " broken-metal " between the sleepers of the adjoining Railway-line, as well as on the roadways where and while abundant durable granophyre abounds !

A list of typical samples secured in the immediate neighbourhood of Bordi during the 22nd, 23rd and 24th July 1915, is hereinunder appended as follows :—

Date.	Regis-tered No.	Provisional Name.	Locality and Remarks.
22-7-15.	68	Whitish-grey Granophyre. Fine-textured, very tough, but superficially weathered and worn. Shows protective coat of secondary material *in situ*.	200 yds. S of Bordi Village on N bank of Dhángawa Vokala, in huge exposed boulders which also form the foundations of the village.

Date	Registered No.	Provisional Name.	Locality and Remarks
22-7-15	69	Fairly fresh specimens of Granophyre, variation of No. 68.	Same site as No. 68. Would repay for being blasted.
22-7-15	70	Felsitic-Sand	Liberated by weathering of No. 68.
23-7-15	71	Coarse Light-Brown Granophyre Weathered but tough. Apparently continuous with Nos. 68 and 69.	Forms many small knolls and slopes, 500 yds. and beyond NNE. of Bordi, locally called Bordi Dhár-ka-Dhárdi.
23-7-15	72	Snowy-white Granophyre. Exceedingly tough; but weathers thinly to yellowish-brown.	Small Excavation by side of Ginning-factory, about 1 mile NNE. of Bordi Worth blasting.
23-7-15	73	Curious variety of 72. Weathers to Smoke-black.	Adjoining No. 72. Probably altered by contact-metamorphism.
23-7-15	74	Laterally-Compressed Dyke of Granophyre, cleaved into slabs about $1\frac{1}{2}$ inches thick.	Cuts through Nos. 72 and 73. The cleaved jointing dislocates the slabs into brick-like pieces.
23-7-15	75	Sample of Limestone broken to gauge for Railway-line.	In Porbandar Territory approaching Sakhpur Station.
24-7-15	76	Brownish-grey Granophyre. Coarse and very tough	About 200 yards NE. of Bordi Village. Blasted for Railway-line.
24-7-15	77	Whitish-brown Granophyre. Coarse, very tough, and with Porphyritic crystals.	Blasted for Railway-line about 400 yards due north of the Village of Bordi.
24-7-15	78	Surface of No. 77 sunbaked to a bright-red to depth of 2-4 inches.	Same locality as No. 77. Where heaps of the blasted material lie unutilised.

The coarse granophyres revealed by the Railway cuttings north of Bordi, extend, superficially exposed all the way southward (SE. by SSE.) for about $1\frac{1}{3}$ miles, to an eminence 441 feet above sea-level called Cocachia Dhár, the west flank of which, sends out a spur of a fine fresh-grey, finely-textured microgranitoid granophyre in large, sound-blocks, even at the surface, which could be profitably utilised for monumental and kindred work. The base of this hill bears a thick deposit of coarse

sandy miliolite of but little commercial value, which however increases rapidly in thickness and improves in quality in a south-westward direction for a trifle over a mile, to terminate at the eastern basal cradle of a high-hill, (679 feet), called Ghojhara Dungar, where fairly brisk quarrying operations are being carried on, through deposits of sound second-grade miliolite, varying in depth from 6 to about 25 feet, and locally known as Ghojhára Khán.

Somewhat more than ½ mile SW. of Cocachia Dhar, the above-mentioned deposits of miliolite are pierced by a natural shaft, nearly vertical and about 20 feet deep through beds of the solid rock. This inlet is rumoured to lead into a cave ("Ghojhára-ká-Bhoira") and subterranean passage, which leads to another cave at a very considerable distance on the south-eastern side of Cocachia Dhár which is accordingly named "Cocachia-ká-Bhoira."

There are no roadways hereabouts; but an excessively rutty and frequently deficient cart-track over miliolite and through a tangle of jungle-growths, eventually leads to open ground about one mile NW. of the small village of Aniáli. Approaching to about 600 yards NW. of Aniáli, there is a well-shaft, which discloses the geological structure of the immediate neighbourhood by showing (from the surface to the underground water-level), 2 feet of a mixed calcareo-felsitic soil, covering about one foot of slabs of miliolite, and finally, some ten feet of calcareo-felsitic subsoil, growing increasingly rich in large fragments of much-weathered granophyre of an originally light-grey colour and coarse texture.

Aniali village is practically built upon a thin shell of coarse, sandy miliolite, overlying a deep layer of rubbly conglomerate which eventually rests upon a solid base of granophyre. This structure prevails, with but slight modifications in the proportionate development of the rock textures named above, and continues WSW. for fully 1½ miles to the base of a south-westwardly trending ridge, the terminal hillock of which is called Vija Dhár.

Vija Dhár is flanked on the east by an unusual thickening of coarse thin-bedded miliolite, but at its westward end, meets the plain below with huge boulders and bosses of ruddy pale-grey and pale blue-grey granophyres of fine to medium textures, and in an apparently fresh and unweathered condition, save for the inevitable thin crust of decay due to epigene reactions.

The samples collected during the abovenoted excursion have been duly registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
26-7-15	79	Microgranitoid Granophyre. Fresh-grey and finely-textured.	Spur from W. flank of Cocachia Dhár,. 1⅓ m. SE. by SSE. of Bordi.
26-7-15	80	Miliolite-Limestone, Coarse to Medium-grained, Hard, Ferruginous, somewhat Fissile 2nd to 3rd grade stone.	Little over ⅓ m. SW. of Cocachia Dhár, near vent of vertical 20 ft. deep outlet from cave called "Ghojhára-ká-Bhoira."
26-7-15	81	Coarse, Light-grey Granophyre. Partially decayed but tough. From subsoil boulders.	Well-shaft, about 600 yards NW of Village of Aniali. From depth of 10 feet.
26-7-15	82	Ruddy, Pale-grey, finely to medium-textured Granophyre. Probably partially sunbaked.	Base of terminal ridge-hillock, called Vija Dhár, 1½mile WSW. of Aniáli.
26-7-15	83	Bluish-grey Granophyre. Apparently quite fresh.	A few yards from site of No 82.
26-7-15	84	Rubbly, Calcareous Stone, with Red-brown Pebbles, etc. Immediately underlying thin crust of coarse Miliolite.	Bed of very Shallow Stream on alluvial Plain of detritus, (calcareo-felsitic), 1 m. WSW. by SW. of Aniáli.

Tents were struck at Bordi, and being no longer required for a continuation of this traverse, were duly despatched to Porbandar on the morning of 28th July, 1915.

At 8 a.m. the eastward route was taken toward the boundary of the State at Barda Choki. The cart-road after about half-a-mile gave place to agricultural tracks which were wearily followed by the edges of and across partially ploughed fields, to stony-ground thinly capped by coarse rubbly miliolite, until the terminal elevation of a very long, low ridge of granophyre was reached about 2⅓ miles, ESE. by E. from the W. end of Bordi. This ridge was traced to rise about 1¾ miles NE. of Bordi, in Navánagar territory, and to trend from NNW. to SSE. to end in the gentle slope indicated above, which is crossed by the cart-track from Bordi to the town of Khirasra. The exposed rock, very plentifully in evidence hereabouts, consists of a whitish-grey, fine to medium-textured granophyre, slightly altered to a dead-white hue superficially,—probably of the nature of kaolinisation. The local name for the ridge at this end is "Bhavawari Dhár"; and it is presumed, from sledge-hammer trials, that an abundance of both useful building-stone

and high-grade road-metalling could be advantageously secured at this site by ordinary gun-powder blasting.

Onward and eastward from this site, the route was taken along the well-beaten cart-track to the town of Khirasra. At first, the surrounding countryside appears to be well-cultivated, proclaiming a goodly depth of soil; and this was confirmed by the examination of a well-shaft on the roadside a few hundred feet E. of the Bhavawari Dhár dyke-ridge of granophyre.

Proceeding eastward and then swerving slightly to the south, for a distance of $1\frac{1}{5}$ miles over an increasingly miliolitic surface, the south-western side of Khirasra is reached by an excessively rutty cart-road skirting the west bank of a wide stream channelled through a thick deposit of coarse buff miliolite which is casually extracted for local wants. This stream in its passage southward to join the River Minsar about $\frac{1}{5}$ mile from the town deepens into a picturesque gorge displaying the false-bedding of the deposits to advantage, and showing the stone at sundry elevations to contain partially rounded large fragments of a previously-formed miliolite. The gorge is eroded steeply on both sides to depths of from 15 to 20 feet entirely through beds of very inferior miliolite.

Taking the beaten cart-road, due S. for about $\frac{4}{5}$ mile from Khirasra mostly over a crust of rough miliolite with scrubby growths of the "Tanner's-Cassia," the bed of the Dhángawa Vokala is crossed, on its way to join the River Minsar, and the route then bends south-eastward to eventually run alongside the River Minsar to an extremely steep declivity which leads to the ford across to the village of Walotra. The declivity is formed by an artificial cutting, which affords an excellent example of the miliolite-base, displaying gravelly and pebbly false-bedded deposits beneath a thick crust of coarse miliolite, and the whole lying upon a very deep layer of earthy and calcareous conglomerate, full of partially-rounded fragments of previously-formed miliolite and of a goodly proportion of basalt, etc., of bedded-lava origin.

Walotra Village reposes on a counterpart in structure of the section just described and overlooks the broad but shallow bed of the River Minsar from its eastern bank. In a direct line E. from Walotra the cart-road runs for $1\frac{1}{2}$ miles to the village of Dyar or Sihor, and from thence at another mile E. by ESE., the track crosses the boundary into the State of Junágadh. The geological structure of the irregular quadrangle bounded on the west by the River Minsar from Khirasra on the north to Samláwadar Nes at the south, may practically be recorded

as a thinning down of the formations noted above to prevail in the neighbourhood of Walotra. It may, however, be observed that the abundant occurrence of pebbles of basalt in the bed of the river, at the Walotra ford, denotes the proximity of bedded-lavas of the Deccan-Trap Series.

Samláwadar Nes, a small milking-station, $1\frac{1}{2}$ miles S. of Walotra-ford and $1\frac{1}{4}$ miles N. of the town of Kandorna, is situated at the N. apex of a triangular area, the other two curvilinear sides of which are formed by the State-boundary bend of the River Minsar, with Kandorna at the S. point of the hypotenuse. This sub-rectangular patch of land is deeply overlaid with rich detrital earth, and, as a consequence, forms an excellent plantation-ground for a thick growth of babuls (*Acacia arabica*), and intermediate shrubs of the tanner's cassia (*Cassia auriculata*) which doubtless add to the revenue of the State, and ought to be more widely cultivated on rock-plains and waste-lands as reclamation agents, and in fitting the soil for agricultural purposes. The babul trees in this plantation, being bereft of continuous sea-breezes, were observed to be losing their "tchutri"—or umbrella habit,—so characteristic of kindred growths in the vicinity of Porbandar City.

Samples gathered during the journey, and détours, from Bordi Village, *viâ* Khirasra, Walotra, Dyar and back, and from Walotra-ford through Samláwadar Nes to the town of Kandorna, were registered as follows:—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
28-7-15	85	Whitish-grey Granophyre, medium to fine textured, and showing opaque-white alteration at weathered surface;—*kaolinisation*?	$2\frac{1}{4}$ m. ESE. by E. from Bordi. The cart-track crosses the last low ridge of this stone; which runs from NNW. by NW., to SSE by SE. Called Bhavawari Dhár.
28-7-15	86	Indurated. Sandy Miliolite-Limestone, in 3-4 in thick beds, broken vertically into bricks forming 1 ft. 6 in. in total thickness, underlying 2 ft detrital soil.	Well-shaft on roadside from Bordi to Khirasra, $2\frac{1}{2}$ miles ESE. by E. from Bordi. Abandoned sinking of well, at a depth of 16 ft. from surface.
28-7-15	87	Rubbly-Miliolite from 3 ft. thick Conglomerate, underlying No. 86.	Same site as No. 86 From 5 ft. below surface of ground,
28-7-15	88	Decayed, Yellow Felsitic-Earth, derived from Granophyre.	Same site forming 10 ft. thickness immediately underlying No. 87.

Camp-Station IV.—Kandorna.

District-Bungalow, N. Outskirts of Town.

CAMP-WORK was commenced from the well-appointed District Bungalow at Kandorna on the morning of 29th July, 1915, when the following observations were recorded in the field-book.

The town of Kandorna, favourably situated on an eminence of gently-sloping ground, is built upon the west-bank of the River Minsar; and sundry excavations on the northern outskirts reveal the geological structure of its foundations and surroundings.

Half-a-mile almost due E. of the centre of the town of Kandorna, there is a small hill of quite a different character from those already observed; inasmuch as its truncated conical contour, known as the "hog-backed" type,—in contradistinction to the rugged peaks peculiar to hills of hypabyssal or plutonic origin,—proclaims it to belong to the bedded-lava formations of volcanic origin, which constitute by far the major part of the province of Káthiáwár. The hill, called Dhanak Dhár, stands 137 feet above the level of the sea, and its south-western flank slopes gently down to the made-road at its base, at a distance of slightly over ½ mile SE. of the District Bungalow on the other side of the River Minsar. Upon this slope, a small pit has been blasted, and from this site, fresh samples of stone were readily secured, and found to be composed of a slightly splintery, densely-textured, pale blue-black Basalt, which breaks with a conchoidal fracture, and is jointed vertically into large transversely-cracked columns, with but slight traces of spheroidal shrinkages.

Dhanak Dhár Basalt admits of being quite easily broken to gauge into an angular shingle suitable for road-metal, and ought to be much superior to the sandy-miliolite and consolidated shell-sand now almost universally employed for macadamising the made-roads of Porbandar State. Its "life", as such, so to speak, cannot, of course, for a moment be put on a par with that of the granophyres; but may be reckoned, roughly, to more than trebly outlast that of the miliolites and kindred calcareo-arenaceous materials, in so far as resistance to attrition or crushing force is concerned.

From Dhanak Dhár, the made-road in a SE. direction was taken for about one mile; and observations of the surrounding countryside E. and NE. to the State-boundary line showed a uniformly fertile region of fairly deep-soiled arable land, largely calcareous, but tempered with

argillaceous matter derived from decayed volcanic rock from below, and sandy-particles of drifted detritus from the hypabyssal heights of the ridges and spurs of granophyres above. This kind of soil, moreover, was found to prevail southward as far as the village of Khijdar on the E. bank of the River Minsar, 2 miles SSE. of Kandorna.

From Khijdar the cart-track, deficient at places, was followed practically alongside of the E. bank of the River Minsar, in a northward direction, to the ford across the river, opposite the north end of Kandorna. A good view of the scarped western-bank of the river is thus obtained, displaying the geological structure of the ground upon which Kandorna is built, in almost diagrammatic fashion ; while it may be also noticed, that the eastern bank of the river has been denuded of most of its miliolite beds, laying bare a surface composed of conglomerate. This conglomerate, on approaching Dhanak Dhár is covered by a gradually thickening shell of undenuded miliolite, which encroaches upon the base and is marked by its line of limitation on the hill-side slope itself.

On the morning of 30th July, 1915, the samples gathered during the preceding day were packed and registered, thus :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
29-7-15	89	False-bedded, Pebbly and Gravelly, Surface Miliolite.	Shallow pits, North side of Kandorna Town.
29-7-15	90	Hard, Sandy, Compact Beds of Usable Miliolite.	Immediately underlying No. 89.
29-7-15	91	Compact Pale Blue-black Basalt..	Dhanak Dhár, blasted pit on S. slope of Hill.

Kandorna District Bungalow was vacated at 8 a.m., and the traverse brought to a close by a return journey, along the highway, from the gate of the Bungalow, " Westward Ho !," to Porbandar headquarters, *viâ* Wadwála, and after a brief halt at Ránáwáo.

It may be mentioned, *en passant*, that the made-road from Kandorna and beyond, right up to Ránáwáo and from thence to Porbandar is now under repairs. The " metal " being used is almost exclusively of the nature of either consolidated Shell-Sand or Sandy, Coarse and Rubbly-

Miliolite ; save where, as in the immediate vicinity of Dhanak Dhár, advantage has been taken of the presence of an abundance of angular basaltic shingle, naturally detached by weathering and drifted down upon the hill slopes adjoining the roadway. This drifted material when examined, was found, for the most part, to be much decomposed and unfit for highway macadamising ; although doubtless quite as strong and durable as the coarse sandy miliolite, along with which cartloads appear to have been alternately and indiscriminately dumped down and spread upon the roadway.

The obvious remedy, in this particular instance, would be to insist upon the contractor making use of the enormous supply of perfectly sound basalt, from the site of the small pit already alluded to as existing on the southern slopes of Dhanak Dhár hard by, and to thereby more than treble " the life " of the highway at a minimum of extra expense for blasting and stone-breaking. From the contractor's view point, however, it would never do to endeavour to save expenses, especially as by so doing, at least two-thirds of his occupation would be gone. The same remarks, to an enhanced degree, may be made to apply to the utilisation of the ubiquitous granophyres of the Barda Group of hills and their respective outliers.

Wayside notes, culled from the pages of the field-book, show that the geological structure of the countryside, with its broad and fertile fields on either side of the highway, is fairly constant, all the way from Kandorna to within a stone's-throw of Wadwála. This may be summed up, by stating that, allowing for insignificant variations, the exposures, eroded stream channels, well-shafts and sundry excavations reveal a fairly deep (2 to 4 feet) layer of detrital soil, overlying a more or less thin and crumbly crust of rubbly miliolite, which, in its turn rests upon a base of limy, pebbly and gravelly conglomerate, of sometimes considerable thickness.

None of the exposures reach down to below the level of the conglomerate, so that it is impossible to note the nature of the underlying formations by direct observation. Nevertheless a shrewd guess, may be made in this connection, from the frequency with which foreign fragments of certain stones occur imbedded in the conglomerate. Time it may readily be inferred that the conglomerate at Kandorna rests upon a foundation of Basalt ; while that to the South of Aniáli may or may not lie upon a base of granophyre ; and it is just possible, that as soon as microscopical determinations are made, that some of these deposits, as well as the conglomerates in the neighbourhood of Wadwála

and onwards to Ránáwáo and Porbandar, will be proved to rest upon Tertiary Strata of Gáj, Limonitic-Limestone.

Under the bridge near by the NE. end of Wadwála, there is a noteworthy variation in the disposition of the sub-superficial layer of limestone. The ground above it has been swept away at places; while a deep trench, extending for about 100 yards southward, has been dug for the excavation of "road-metal." The beds of limestone immediately below the bridge assume by reason of weathering, a shaly appearance; in slabs varying from the fraction of an inch to several inches in thickness. Farther, (about 100 yards) south, these slabs increase in thickness to the extent of from 1 to 2 feet or even more, and it is from these bulkier pieces, (which, in common with the thin shaly bits, consist of coarse-grained, sandy, gravelly and highly-ferruginous limestone), that the "road-metal" is taken. The limestone rests upon a pebbly, sandy, and very limy conglomerate, which has been excavated to a present depth of 5 to 8 feet, to yield road-dressing material.

Proceeding WNW. along the highway from Wadwála, the fields on both sides are seen to be thickly strewed by the thin shaly slabs of sandy-limestone for a distance of about two miles, to the west side of the Police Choki, here noted as a landmark, where the broken crust of limestone vanishes and the underlying conglomerate-base tails down at the surface, to a diverticulum from the swamps of the great Salt Marsh which stretches to the south at a distance of a trifle over two miles SW. from the Police Choki. Beyond this arm from the body of the great marsh, the westward lands show varying outcrops of sandy-limestone and shell-sand;—details concerning which have already been recorded.

The following samples were duly added to the register of rocks:—

Date.	Registered No.	Provisional Name	Locality and Remarks.
30–7–15	92	Shaloid Limestone ..	.. below Bridge, just E. of Wadwála
30–7–15	93	Earthy, Calcareous Conglomerate.	Underlying No. 92.
30–7–15	94	Marly Ferriginous, Gravelly Limestone, in thick slabs.	Replacing shaloid beds 100 yds. S. of No. 92.
30–7–15	95	Large, partially-rounded bit of former Miliolite in Earthy, Limy Conglomerate.	Shaft of 25 ft. deep new well on S. side of road, opposite 13-m. Milestone from Porbandar.

DIGEST OF DIARY.

August, 1915.

CAUSE FOR SUPPLEMENTARY FIELD-WORK, in connection with the results of the first traverse above recorded, was occasioned on the 15th and 16th days of the current month as follows :—

In compliance with an Order from the Administrator, that the Director of the Geological Survey should consult with and assist the State Engineer, in the construction of a highway from the town of Ránáwáo to the mountain-retreat of Khambála, the Director, accompanied by the Assistant Engineer, proceeded by the 11-20 a.m. train from Porbandar on Sunday, the 15th instant, to Ránáwáo. From the town of Ránáwáo, the cart-track to Bordi was followed as far as the pass between the hills already noted *

This journey was projected for the purpose of pointing out the sites of suitable material for metalling the highway, situated within easy distance of the proposed line of route from Ránáwáo to Khambála ; and detailed explanations of the Director's views concerning the choice or rejection of available materials, coupled with field demonstrations on the spot, together with suggestions on the construction of an ideally perfect and permanent highway were afforded from time to time during the journey.

Within the limited time at disposal, détours were made to a small outlying mound of finely-textured blue-grey granophyre, and to its reappearing outcrop by the side of the roadway, bounding the north-westward confines of the Naliadhár State Jungle-reserve. It was pointed out that this stone, by reason of its texture and mineral constitution is not prone to weather deeply, and that its spheroidal shrinkage-nuclei are scarcely affected at all, even under conditions of prolonged exposure to epigene reactions. Hence, it was recommended, that the fresh boulder-like blocks which lie exposed in great abundance, should be broken to gauge and utilised for metalling one definite section of the proposed highway. The stone in question has been registered in the collection as No. 59

Registered No. 62, provisionally called a grey-brown, light-coloured, medium-textured granophyre, from the hill-spur, running from NW. to SE. alongside the cart-track, about 3 miles NE. of Ránáwáo *en route* to Bordi, was next examined and pronounced to be superior to the first

* *Ut supra* pp. xvi, xvii.

sample for resisting attrition and severe stress. It was pointed out that practically inexhaustible quantities of material are here available by the side of, and indeed, also underlying the line of proposed roadway at this part ; but that blasting operations would be desirable to procure the material at its freshest and best. Attention was also called to the fact that the exposed upper portions of the rock, have been sunbaked to a ruddy hue for several inches internally, but that the effect of this has been beneficial rather than otherwise, in intensifying the hardness of an already tough and strong texture. Sundry specks and patches of a greasy lustre and rusty-greenish alteration products also occur, and probably affect the cores of the felspar units of the rock-mass only, without in any way affecting its total strength and durability.

As affording a contrast, worth noting in the discrimination of granophyric rocks for economic purposes, the Assistant Engineer was next led to the eastern side of the pass through which the cart-track wends its way to Bordi. The rock registered, as No. 63, and designated *pro tem.*, as a "pale blue-grey, fine-textured, sound, fresh granophyre," forming the base of the hill or spur-ridge called Bora Dubba, 3½ miles NW. of Ránáwáo, was found, when *en masse*, to break with difficulty under the sledge-hammer ;—thereby conveying a false first impression of its utility for road-making purposes. When, however, detached large fragments were subjected to further crushing they were found to fracture irregularly into both splintery and small polygonal pieces, thereby proclaiming their unsuitability for road-metalling. There can be but little doubt that the rock-mass although intensely hard, is partially felsitic or crypto-crystalline in intimate structure, and this presumption would, of course, instantly account for its behaviour under conditions of repeated blows or continuous stress, such as obtains on heavy traffic roadways.

By way of contrast to the above, and in proof of the fact that practically the same molten magma, when solidified under other conditions is manifested by textures of widely different physical properties, the continuation of the ridge on the other side of the pass was next examined and found, to consist of a medium to coarsely-textured, ruddy, brown grey granophyre, with yellow-green alteration products, occurring in exposure as large spheroidal boulders, in aggregate ; to form an outlier fringed with rubbly miliolite, but distinctly traceable to the spur of the adjoining ridge-hillock, within the boundaries of the Naliádhár State Jungle-reserve. This rock is extremely tough and strong, and although superficially weathered, would yield, when blasted, ample supplies

of excellent, durable road-metal for the local continuation of the highway which is to run practically by the side of the site.

Samples of all the abovementioned stones, were trimmed on the spot and handed to the Assistant Engineer for future güidance in the selection of suitable materials, and precautions were taken to carefully point out exactly what portions of the rock-mass should be rejected when dealing with exposed material, and especially with reference to the mixed " drift " which is frequently so plentifully strewed upon the slopes of the hill-sides and minor elevations.

Opportunity was taken on the 16th August, 1915, to fill in the gap indicated on page xii of this report, by covering the hitherto untraversed area lying for about a couple of square miles eastward of a base-line from the town of Ránáwáo to Ránáwáo Railway Station. With coolies to carry samples, the whole of the area was traversed on foot, and found to be constituted at the surface, between Ránáwáo and the Railway-line and continuously to the east, by a rock-plain of alternating outcrops of rubbly beds of solid but inferior miliolite, diversified towards the Railway-line by thick ridges of inferior miliolite.

North of the Railway-line, the ground rises markedly to form a long ridge or nether hill, called Bhatwari Dhár, the summit at its highest elevation being 260 feet above the sea level. This ridge runs from SW. to NE. for nearly one mile eastward of Ránáwáo Station, and is composed of a dark blue-black basaltoid rock, exposed in large spheroidal boulders, which,when broken,show the material to be quite fresh under a thin pellicle of deep-red, probably hæmatitic weathered matter. When the rock is manipulated, however, it is prone to unexpectedly snap sub-rectangularly, so that it cannot be recommended for building-blocks nor yet even for paving setts ; but the tough shingle into which it can thus be easily reduced might nevertheless serve admirably for road-metal, as it is not by any means fissile, but breaks into hard cuboidal fragments, to the regulation gauge of from 1 to 1½ inches. At all events, the stone is worthy of a trial, as very much superior to the sandy miliolite or shell-sand rubble, now so much in vogue ; and, on account of its abundant development at a specially favourable site for being continuously quarried and conveyed to centres of consumption and distribution by the adjacent Railroad.

Bhatwari Dhár, at its base, supports a considerable deposit of miliolite, which, when superficially examined, appears to be of good merchantable quality. Trials pits on the hillside, however, have shown

that sound building-blocks cannot be secured in sufficient quantity to justify quarrying, as the good material is much too frequently interlaminated with inferior or loosely coherent layers.

Coming down once more to the level of the Railway-line, good exposures to show the geological structure of the ground are afforded by the cuttings which commence at about ½ mile ENE. of Ránáwáo Station.

These exposures are particularly interesting, by reason of displaying to advantage the phenomena of columnar jointing coupled with spheroidal shrinkages so prevalent among the hypabyssal rocks of the Barda group of hills.

Continuing along the Railway-line in its north-easterly direction, the line itself emerges from the cutting to the natural surface of the ground, and, at places, above it ; to subsequently pass through rising ground formed by the tailing down of a spur from the northward heights at a distance of about 2¾ miles ENE. by NE. from Ránáwáo Station. This spot also marks the ENE. termination of Bhatwari Dhár while the lofty peak by Khára Vira looms clear in the distance due N. The southward trending hill-spur, which is encountered by the railroad, is bounded on the E. by a mountain runnel, called Dorivav, which is said to come all the way from Khambála ; and, on its immediate W., by an obscure dyke of comparatively small dimensions, which has been revealed by a ditch-like excavation on the north side adjoining the Railway-line. Upon examination, this accessory dyke appears to have been intruded under conditions of sufficient lateral compression to render the rock-mass liable to split at parts into slabs ; but towards its central portions these slabs become so thick (one to two feet or more) as to be no longer recognisable as such. The stone of this dyke consists of a light blue-grey granulitoid granophyre in a tolerably fresh condition ; albeit its lateral portions are prone to be sub-fissile.

It subsequently transpired, that the writer was told by one of the road surveyors, that it was to this very site that the STATE ENGINEER, took MR. MEASHAM LEA, the Chief Engineer of Karachi Municipality, in quest of stone suitable for heavy-traffic road-metalling; but that the stone was rejected because of its apparent tendency to split. It is clear that this misapprehension must have arisen from a cursory examination of only a part of the lateral edges of the dyke, which by reason of intense pressure, (dynamic metamorphism), had undergone a kind of pseudo-cleavage. The central portion of the same dyke, if carefully scrutinised would have been found free from such defects ; and it may be presumed,

that it was from that source that a limited quantity of material was formerly extracted and used for making the strong steps to the Madressa Library and School Buildings opposite to the Porbandar State Secretariat.

Had the exploring party abovementioned taken the trouble to walk about twenty yards or so farther, to the high pile of huge spheroidal boulders, which cap the base of the southward trending spur adjoining and cut through by the Railway-line, they would have been amply rewarded by the discovery of an admirable quarry-site for just the very kind of stone they were looking for; namely, a particularly tough and strong, medium-grained light brown-grey granophyre, samples of which were collected and registered as No. 101.

Additions to the general collection are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
16–8–15	96	Granophyric Felsite. Light-grey with dark-grey spots. (spherulites ?). Resembles No. 34.	Railway-cutting nearly ½ m. ENE. of Ránáwáo Station. From core of spheroid of column.
16–8–15	97	Miliolite-Limestone. White, but prone to vary into rusty and inferior coarse laminæ.	Half-way up side of Bhatwari Dhár, N. of No. 96, near to the limestone limit.
16–8–15	98	Dark Blue-black Felsitic Rock in large spheroidal boulders. Fresh and very thinly weathered, but apt to fracture sub-rectangularly in unexpected directions, when manipulated.	Summit of Bhatwari Dhár, a long nether-ridge at base of Bhatwari Dungar. Runs SW. to NE. for nearly 1 m. eastward of Ránáwáo Station. Weathered surface-pellicle is hæmatitic.
16–8–15	99	Rubbly Miliolite full of Brecciated Inclusions.	About 1 m. ENE. of Ránáwao Station :—Railway-cutting.
16–8–15	100	Light Blue-grey Granophyre Dyke slightly excavated. Cleaved at edges only.	N. side of Railway-cutting, about 2½ m. ENE by NE. of Ránáwáo Station.
16–8–15	101	Light Brown-grey Granophyre. Medium textured, slightly sunbaked, and with greenish alteration products. Tough rock.	In huge spheroidal boulders of spur from Khara Vira Dungar Adjoining N. side of Rail-road 2¼ m. ENE. by NE. of Ránáwáo Station

With the exception of the field-work recorded above, the whole of the remaining days of the month were very fully utilised by work in the office; designing and supervising fitting and furnishing for the

workshop and laboratory by the mechanic ; and preparing material for both workshop and laboratory operations, pending the arrival of instruments and accessories from England.

DIGEST OF DIARY.

September, 1915.

WITH THE EXCEPTION of a few excursions, details of which will be recorded in the sequel, the whole of the month of September 1915 was passed at headquarters in Porbandar for the purpose of completing workshop and laboratory arrangements preparatory to the detailed examination of the large collection of specimens secured during the first traverse through the State.

On Monday, the 6th September 1915, the Director accompanied by his Assistant, proceeded in his curricle, along with the contractor HAJJI ESMAIL, HAJI DADA, to Ránáwáo, with the two-fold object of indicating suitable quarry sites to the contractor for the extraction of high-grade granophyres for the supply of Karachi Municipality, and to cover the same ground with the State Chief Engineer and Assistant Engineer, in quest of road-metalling material adapted for trials on heavy-traffic highways.

A halt was called at the E. end of the bridge spanning the Creek, on the Ránáwáo Road about 2½ miles eastward in a direct line from the centre of Porbandar City, for the purpose of securing a photograph of the site, where a small exposure, shows a thin deposit of coarse miliolite, overlying Tertiary beds, just barely shown at the surface. The spot marked by a group of "Tchutri" or Umbrella Babul trees, (*Acacia lanifrons*), said to be peculiar to Porbandar.

Ránáwáo Station was reached after a drive of about an hour-and-a-half at 10-30 a.m., and the sunlight being favourable, a walk was taken for about ½ mile ENE. along the Railway-line, and a couple of excellent photographs were taken of the cutting on the N. side of the line, to show the characteristic spheroidal-shrinkage structure of the hypabyssal fivke-rock, there artificially exposed, at 11-30 a.m.

On return to Ránáwáo Station, in time for the train from Porbandar, the Chief Engineer and party were met and accompanied on the Quarry-Siding trolly to the heights of Adatiána, stopping, by the way, to visit the cave,—"Jambuvanti Bhoira." A cursory examination of some

of the granophyric rocks adjoining the Railway Siding was made, but adjourned, as the time at the disposal of the Chief Engineer did not permit further investigation.

Notes to indicate exact sites suitable for quarrying typical granophyres adapted for road-making operations were provided, with instructions to the Clerk of the Geological Survey, to accompany the HAJJI ESMAIL to the Ádatiána Heights and to bring back samples of stone for comparison with those previously registered. This was done on the 7th instant, and the samples brought back were found to correspond with those in the registered collection.

On the 8th instant, an excursion was made under the guidance of MR. JAIKRISHNA INDRAJI (the talented author of a comprehensive work, in Guzerati, on the "Flora of Barda Mountain"), to the Dwarkadish Gardens, in the Bokhira Village limits, about one mile nearly due N. of Porbandar City, with the two-fold object of taking botanical specimens and making notes on the geological structures exposed by a recently sunk large well-shaft on the immediate N. side of the gardens. In the well-cultivated garden-grounds, MR. JAIKRISHNA drew attention to a finely developed tree in full fruit, which is said to be the only one of its kind in Káthiáwár, and the plant was identified by the Curator of the Herbarium, (C. C. CALDER, ESQ., M.A.), at the Royal Botanic Garden, Sibpur, Calcutta, as a fine specimen of *Diospyros discolor*.

During subsequent conversations with MR. JAIKRISHNA on the geological influence of plants in their direct bearing upon conserving, improving and reclaiming land, it occurred to the writer, that much valuable work, affiliated to the geological survey of the State, might be done with the co-operation of MR. JAIKRISHNA, in supplementing the collection of economic stones with specimens and informatory notes on the flora of the country-side.

MR. JAIKRISHNA next led the way to the site of the recently sunk large oblong well-shaft on the N. outskirts of the Dwarkadish Gardens, which proved to be exceptionally interesting as throwing additional light on the geological structure of the superficial sedimentary deposits of Porbandar. It was found on this, and on a second visit to the site on the 15th instant, that the well-shaft, now holding about 10 feet of clear and passably potable water, had been sunk to a total depth of 26 feet from the rocky surface;—the land, at this part, being also about 26 feet above the level of the sea. The upper portion of the shaft had unfortunately been obscured by a lining of stone, but it was found that the

surface, practically soilless, was composed of deep beds of russet-coloured, indurated and somewhat honeycombed limestone. At a depth of about 14 to 16 feet, a band of from 2 to 3 feet in thickness of compact, yellow, limonitic-limestone could clearly be discerned; while below that were observed, beds of rubbly conglomerate, which probably extend down to the bottom of the well. From the heaps of excavated débris, it was easy to select samples of the compact yellow stone, which was identified as a Miocene fluvio-marine deposit essentially similar to the variety of Gáj limonitic-limestone, named "Pindáralite"; while the upper strata of the underlying rubbly conglomerate, was found to be rich in characteristic Miocene fossil remains.

To unravel the true nature of the beds, (intervening between the surface limestone and the Gáj limestones and conglomerates), hidden by the well-shaft lining, the country-side was searched for other artificial or natural exposures; and, fortunately, on the 15th inst., a particularly well-defined scarp was found flanking the north side of a fosse at the north end of the Victoria Jubilee Bridge, Porbandar, or only about 350 yards to the south of the new well-shaft. This exposure showed about 1 to 2 feet of honeycombed miliolite, overlying from 4 to 5 feet of compact beds of Consolidated Shell-Sand referable to the Dwárka or Post-Pliocene Beds; while the base of the cliflet was constituted by a limy conglomerate full of fragments of Gáj limonitic-limestone.

DIGEST OF DIARY.

October, 1915.

During the month of September, which was passed at head-quarters, sundry local samples were added to the collection of geological specimens, as follows:—

Date.	Registered No.	Provisional Name	Locality and Remarks.
8-9-15	102	Deep-Ruddy, Sandy and Indurated Limestone.	About 1½ m. nearly due N. of Geol. Surv. Bungalow. Surface of ground.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
8-9-15	103	Gáj or Limonitic-Limestone, Pindaralite-type.	A few feet below 102, from new well-shaft, just by Bokhira limit.
8-9-15	104	Fossiliferous Conglomerate ..	Underlying 103.
15-9-15	105	Much-Cancellated Coarse Miliolite-Limestone.	S. side of Fosse. Surface of 3 ft. scarp-cutting, at N. end of the Victoria Jubilee Bridge, Porbandar.
15-9-15	106	Denuded Top of Honeycombed Miliolite,—1 to 2 ft. thick.	N. side of Fosse. Top of 6 ft. scarp. Same locality as 105.
15-9-15	107	Indurated Shelly-Limestone. Probably Dwárka-Beds Group.	Immediately underlying 106.
15-9-15	108	Indurated Shelly-Limestone with Brecciated Gáj Fragments.	4 to 5 ft. of Beds underlying 107.

The deep-ruddy limestone, No. 102, is only superficially developed and prone to be much too cancellated at places and to vary considerably even within restricted areas. Fairly large blocks of the material may however be secured and turned to good account by being carved into ornamental articles such as vases, clock-cases, etc.; but a constant supply cannot be depended upon.

Underlying this limestone, there is a considerable depth of rubbly conglomerate, with concretionary nodules, and the remnants of consolidated shell-sands of the Dwárka group of beds, which latter are better developed and exposed by the scarped cutting at the N. end of the Victoria Jubilee Bridge, Nos. 107 and 108. These stones, the counterparts of which reappear along the coast-line from the custom-house to beyond the Palace at Porbandar, are very much harder and more durable than the overlying miliolite, and capable of yielding valuable building blocks and sounder wastage for road-metalling than the rubbly-limestone now being used. At the sites indicated, however, the ground is not only unsuitable for being quarried, by reason of its low-lying and practically undrainable position ; but is not available on account of being wanted for building and other purposes. Nevertheless, it is more than probable that other more favourably situated sites for the extraction of this excellent building stone may yet be brought to light.

Deeper down,—below the Dwárka beds of consolidated shell-sand,—No. 103, demonstrates the presence of a bed of from one to three feet thick of a finely-textured, yellow limonitic-limestone of the Gáj, or Miocene deposits;—called by the writer "Pindáralite," from having first been found typically present at the village of Pindára in Navánagar State. Here also, the site is not suitable for being quarried; but, from the reliable records of FEDDEN, it is anticipated that workable outcrops of the stone may yet be found in the State to yield a profitable supply of both useful and ornamental material.

Camp-Station V.—Ranawao.

SW. Outskirts of the Town.

ARRANGEMENTS for a second traverse of the State, to cover the country-side to the N. of a base-line from Porbandar City to Ránáwáo Town and to the W. of the Barda group of hills, having been satisfactorily concluded, the Director drove from headquarters at 9-45 a.m., across the Victoria Jubilee Bridge, *viâ* Kolikhara on the main-road, and thence by the turning of a cart-track in a north-easterly direction over an exceedingly level plain, past the new hamlet of Nawágám, and thereafter by sundry slight turnings over rubbly limestone into a by-path leading to the south side of Ránáwáo Railway-Station. The camping ground formerly occupied was reached at 12-45 p.m., but although the tents had been despatched on the previous day, only the pole of the châlet-tent had been pitched, as the tentman could not, during the absence of the Mamlatdar, get enough assistance. It was therefore late in the evening before the tent furniture could be arranged; and work, consequently, had to be postponed to the following morning.

During the journey, opportunity was taken of the bright sunlight to secure a distant, bird's-eye panorama of the Barda Hills from NW. to SE., to show the limestone limit of the extensive quarry-sites on the Adatiána heights.

Previous arrangements having been made with the Quarries-Clerk to accompany the Director and party to the quarry sites, and also to point out to the HAJJI ESMAIL, exactly where he should peg out his Prospector's-Claims, a couple of coolies provided with sledge-hammers and collecting gunny-bags, were sent on beforehand, and met the prospecting party, at Ránáwáo Station at 9 a.m. on 11-10-15.

Smart walking, ENE. along the Railway-line for about a mile, and then turning nearly at right angles northward over rough miliolite under foot, through jungle-scrub, past the limestone limit, and onward and upward over débris and big boulders,—altogether an ascent of fully half-a-mile,—brought the party to the brow of the highest summit of the nether hill, named Bhatwari Dhár, some 260 feet above the sea level. The huge spheroidal boulders hereabouts are blazed with white, as a sort of temporary landmark; and here an enormous quantity of deep blue-black boulders, stretching on either side for many hundreds of yards, and exhibiting, when tested at intervals, a wonderful uniformity in colour and texture, were indicated and pegged out, for a quarry-site of No. 98 on the Registered List, provisionally named a Dark Blue-black Basaltoid Rock, in large spheroidal boulders, fresh, and very thinly (weathered) covered by a pellicle of bright-red hæmatitic matter; but apt to fracture sub-rectangularly, when smartly struck, in unexpected directions. This stone, which is incomparably superior to even the hardest and toughest limestone, admits of being readily broken with ordinary native hammers into polyhedral shingle of any desired gauge, and ought therefore to be welcomed by road-makers who are not provided with modern stone-breaking machines. A direct cart road from the Ránawáo Station East-Siding could be inexpensively constructed to several favourable sites for Quarry-backs on the hill-slopes, and work could thus be carried on continuously, irrespective of the monsoons, as there is ample opportunity for a very perfect, controllable system of natural drainage.

At the summit of Bhatwari Dhár, while approaching the base of Bhatwari Dungar in a northerly direction, the powerful direct reaction of the sun, alternating with monsoon conditions, have jointly served to partially laterise the surface stone to varying depths; so that parts of the ground-mass of the rock are rendered ruddy, while other portions are changed to a slaty hue, serving thereby to endow the texture with a pleasing ornamental appearance, which would doubtless be enhanced by polishing. This sunbaked variety of the Bhatwari Dhár stone, No. 109, becomes clearly apparent at about 200 yards or so from the south brow of the hill and prevails for a considerable distance towards the base of Bhatwari Dungar.

On descending the southern slope of Bhatwari Dhár towards Ránáwáo Station, a subsidiary dyke of hypabyssal basaltoid rock was detected, showing a transverse vertical-cleavage of the mass, into small slabs

of one to two inches thick, and samples were secured as likely to prove of scientific interest. The dyke was noted to run from N. by NNE., to S. by SSW., on the west side adjoining a small hill-side runnel.

It was 12-45 p.m. before the quarries-clerk and trolly could be got ready for proceeding to the granophyre quarry-sites on the heights of Ádatiána. On reaching the commencement of the miliolite series of quarries, the line was found to be blocked by loaded wagons, and further progress had to be made on foot, to cover several miles of very rough ground, during which suitable sites were pegged-out for the extraction of No. 33, specified as the Khoria Dhár site for medium-textured, tough grey granophyre for Karachi Municipality samples.

Although not called for by Karachi, other high-grade stones in this region were re-inspected, and quarry sites indicated for future operations to the HAJJI ESMAIL for inclusion on his prospecting license, as follows:- No. 38, a fine to medium-textured, very tough, ruddy-grey granophyre, pegged out as the Mor Chupra Dhár site; No. 39, a medium to coarse, pink and black-grey granitoid granophyre, of highly ornamental appearance, adjoining the miliolite quarry No. 158, near the railway-siding line; and No. 112, a medium-textured, ornamental pink and dark-grey granophyre, forming a good "back" at the base of part of Mor Chupra Dhár, 100 yards or so by a tortuous cart-track from the Miliolite-Quarries Nos. 109, 110 on the Railway-Siding. Good samples of all of these stones were taken to either replenish or supplement the stock and collections at headquarters, and a return to camp was made at 6 p.m.

On the following day, 12th October, 1915, a thunderstorm and very heavy shower of rain ensued and confinement to camp was utilised by packing, trimming and registering the fairly large collection of samples that had been made.

On Wednesday, 13th October, an exceedingly heavy day's work was accomplished. Starting in the gharry accompanied by one cart at 7-30 a.m., the road from Ránáwáo, towards Bordi was taken, and the vehicles being left on the cart-track, the journey was followed on foot to the site of sample No. 47, provisionally specified as a light blue-grey doleritoid rock, situated about 2¾ miles NE. of Ránáwáo Town and about one mile S. of the Railway-line. A couple of outcropping sub-oval mounds of this stone were pegged out for the HAJJI ESMAIL, and a tramp north-eastward to the Railway-line, brought the prospecting party to the spur from Jerickhia Dungar, which crosses the Railway and then vanishes to outcrop again about 150 yards S. of the line, estimated to lie some 3 miles ENE. of Ránáwáo Station. Another quarry-site was

pegged out here as the locale of No. 55, registered as an exceedingly tough pale blue-grey granophyre, sunbaked to ruddiness in patches. This outlying portion of the spur of Jerickhia Dungar is continued as a series of mounds affording good quarrying sites all along in a south-eastwardly direction, where as No. 57, it assumes a somewhat finer texture and affords abundance of sound, fresh, high-grade material for dock work and road-metal.

The gharry and cart which had proceeded along the rough cart-track *en route* for Bordi, were joined by the party on foot, with specimens, at the NW. corner of the Naliádhár State-Jungle Reserve, where the roadside is flanked by a long NW. to SE. spur from the "everlasting hills." This was pointed out as an admirable quarry-site or series of sites, for securing enormous supplies of strong and durable sound building stone and high-grade road-metal;—registered, under No. 62, as a grey, brown, light-coloured, medium-textured granophyre.

Proceeding by cart-road through the hill-pass which emerges near the base of Piara Dungar, called Javantára Gárá, along which the Railway passes eastward, a halt was called for the purpose of securing, if possible, better samples of the ornamental felsite, No. 65, (mottled pale blue-grey and ruddy brown-grey) for the State Collection.

Finally, a rapid run was taken to the village of Bordi and from thence, by the south-eastern cart-track for a trifle over a mile to the base of the isolated outlying hill called Cocachia Dhár, where a quarry-site was pegged out for the extraction of No. 79;—registered as a fresh-grey, fine-textured microgranitoid granophyre, which forms a large, freely-jointed exposed dyke, flanking the sides towards the base of the west spur of the hill.

In searching for a suitable spot for initial operations, it was found that this hypabyssal dyke appeared to have been invaded on its northern side by another dyke of a different character and probably of subsequent formation. This stone, which does not seem to be present in sufficient quantity to justify the opening of an independent quarry, has been registered as No. 113, under the provisional name of Black Basaltoid Dyke-Rock. The exposed surface of the dyke is closely and subrectangularly jointed into oblong blocks varying in dimensions from a few inches up to about a foot or so;—cubic.

On Saturday, 16th October, a few specimens of slag from former iron-smeltings at Ránáwáo having been brought into camp, with the information that iron-ore had been excavated locally, a special journey

was made, to cover the hitherto unvisited ground south of the town. Following the cart-road from the SE. end of the town, more or less adjoining the course of the local stream, called the Dhabukli Nuddy, a slightly elevated patch of deep-red ground, of about 500 yards or so in diameter was reached, $1\frac{1}{4}$ miles S. by SSW. of Ránáwáo, where a few pits had recently been dug by some curious person, at the site of the long-since abandoned "iron-mines." The rock was found to consist of typical laterite, fairly rich in iron-ore. Other minor patches left no room for doubt, that the site represents the remains of a denuded cap of a lateritic ridge, coextensive with other outcrops at Bákharla and beyond.

Slightly eastward, at about the same parallel, there is an ovate hillock, some 3 furlongs in major axis, called Chorkhada Dhár, whence small supplies of tolerably good building-blocks of miliolite are being extracted, which throws an interesting side-light on the geological history of the country-side. The denuded miliolite is found to pass gradually into a miliolite-conglomerate, full of both angular and rounded fragments of laterite, and evidently also of Gáj limonitic-limestone. From this, it may be inferred that the sea of the Miocene Period must have encroached upon the land, quite up to the base of the Bardas in this part of the Province.

Laterisation of the bedded-lavas must also have been fairly extensive throughout the neighbourhood of Ránáwáo; for, upon an examination of the scarped beds of miliolite and their underlying deeply-laid conglomerates which are exposed by the erosion of the Dhabukli Nuddy, from near Chorkhada Dhár right up to within a stone's throw of the town of Ránáwao, characteristic large fragments of altered laterite and laterite-pebbles are met with in abundance, as shown by the typical specimens, registered as Nos. 116 and 117. on the subjoined list.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
11-10-15	109	Ruddy-Grey Sunbaked Incipient Granophyre	Same dyke as 98, but about 200 to 500 yds. along summit of Bhatwari Dhar from S. brow of hill.
11-10-15	110	Cleaved Rock Subsidiary Dyke from N by NNE. to S. by SSW.	Near gorge on S. slope Bhatwari Dhár, near Ránáwáo Station.

Date	Registered No.	Provisional Name.	Locality and Remarks.
11-10-15	111	Ruddy-grey Granophyre. Sun-baked. Strong, medium textured.	Bhatwari Dhár Summit, 400 yds. N of S brow of hill.
11-10-15	112	Ruddy-grey Granophyre. Medium to coarse. Good quarry site by side of rough cart-track.	Base of Mor Chupra Dhár, 100 yds. roundabout track from Quarries 109, 110, Ádátiána Heights.
13-10-15	113	Black Dyke-rock. Adjoining N of No. 79.	Spur of Cocachia Dhár near Bordi
16-10-15	114	Laterite Formerly dug from this slightly elevated patch for iron smeltings. The patches hereabouts, aggregate about 500 to 600 yds. sq.	Surface of ground slightly W. of Chorkhada Dhár, and 1¼ m. S by SSW of Ránáwao Town
16-10-15	115	Miliolite-Limestone. Good second-grade, lying 10 to 12 ft thick upon Gáj (?) beds	Chorkhada Dhár Khán. Small quarry for local use, 1¼ m. S. by SSE. of Ranáwáo.
16-10-15	116	Miliolite-Conglomerate, with Gaj and Laterite pebbles, etc.	Underlying and partially intercalated with 115
16-10-15	117	Miliolite-Conglomerate, with large Laterite pebbles, etc.	E. scarp of Dhabukli Nuddy. ½ to ¼ m. due S. of Ránáwáo.

Camp-Station VI.—Bakharla.

Field, Adjoining E. end of Village.

TENTS WERE STRUCK at 8 a.m. on 22nd October, 1915; and, leaving Ránáwáo in carts, at 9-14 a.m., arrived at Bákharla at 1 p.m., so that the Camp could not be arranged for work till 4 p.m. Tents were pitched by the side of a solitary clump of four "Khijdo" trees (*Prosopis spicigera*) in the middle of a field of fertile arable ground adjoining the east end of the village, and within easy distance W. of a well-shaft with plenty of fairly good potable water.

Driving from Ránáwáo, the direct road in a north-westerly direction over the Railway level-crossing, to the W. of Ránáwáo Station, was traversed, over old ground, on the way to Ádatiána. The light being favourable, stoppages were made, by the wayside, to secure distant views, with the Kodak, of the Barda Hills, to indicate the position and

limestone-limit of the extensive series of quarries on the Ádatiána Heights.

From Ádatiána village, resting upon a rough but comparatively shallow substratum of miliolite overlying a deep layer of earthy, ultra-calcareous, partially concretionary conglomerate, often more than 30 feet thick, at places, the high-road to Porbandar, now being repaired, was followed, SW., for half-a-mile, to where it is crossed by the north-westerly cart-track to Bákharla. The ground surrounding this track, is fairly fertile when cultivated ; but is apt to be covered, at parts, by from one to three feet of more or less solid limestone, and to be covered in its turn by rich detrital soil derived from both the miliolite and the weathered felsitic material from the Barda slopes.

Crops appear to thrive all the way along, wherever they have been tried, until well beyond the south-western limits of the small village of Boricha ; but, upon approaching Bákharla on the NW., the land, for an area of about half-a-square-mile, becomes unaccountably barren ;—not even a termite's mound can be discerned hereabouts. Indeed, the sterile patch is sharply indicated by the sagacious "white-ants," who build their wonderful pyramids, just immediately beyond the bounds of the forbidden ground. A well-shaft in the latter yields mawkish, brackish water, and all attempts to grow anything beside its weakly weeds and sedges, have signally failed. It is probable that the place represents the remains of a saliferous tarn of sub-recent date.

Upon cursory examination it was found that the south side of the village of Bákharla rests upon partially exposed beds of coarsely textured, indurated, consolidated shell-sand of the Dwárka group of beds which, towards the north end of the village, overlap the denuded surface of laterite ;—probably of Eocene age. Eastward, the shell-sand full of laterite fragments and pebbles, thins down, and is in its turn covered, by deposits of miliolite-conglomerate, crowded with shell-sand and laterite fragments. The miliolite deposits grow thicker and purer in progressing east, until they reach their maximum in the cradle of the Barda hills at the base of Dhárfaria Dungar, in the area of the Ádatiána State-Jungle Reserve, which lies to the NNW. of the northern termination of the Railway-siding to the great miliolite quarries of the Ádatiána Heights.

Underlying these enormous deposits of miliolite, there are varying thicknesses of miliolite-conglomerate, the clastic constituents of which are naturally characterised by a dominance of either fragmentary or

rounded stones derived directly from the underlying and adjoining formations. For example, at the east end of Bákharla, about 500 to 1,000 yards from the village, the deep deposits of miliolite with appreciable thicknesses of underlying conglomerate which obtain at the immediate base of Dhárfaria Dungar, about 3½ to 4 miles away, dwindles away to a mere crust of superficial stone, which, however, is underlaid by a very thick deposit of conglomerate, often more than 30 feet, in several of the local well-shafts.

This conglomerate consists in its upper parts, principally of a limy earth, holding large and small fragments of former miliolites ; decayed blocks of felsitic matter, granophyres and so forth ; with sundry rubbly stones of concretionary origin ; while at its lower depths, there is an increasing proportion of chunks of hard miliolite-conglomerate crowded with either laterite-pebbles, shell-sands, and Gáj limonitic-limestone particles or mixtures thereof.

As already noted, the conglomerate, in its turn, tails down, on approaching Bákharla, to overlap the consolidated shell-sand of the Dwárka group at the south and the laterite on the north side of the village. An abundant supply of somewhat " hard " yet potable water is therefore obtained from well-shafts east of Bákharla at depths of from 20 to 30 feet.

On Sunday, 24th October, a drive was taken to the village of Boricha, a distance of about two miles, over level land, partially cultivated and occasionally barren or under grass. The gharry was sent on to the abandoned village-site of Alaswána, two miles farther north, and the prospecting party proceeded on foot, by a little-used cart-track to the base of the hills, keeping ENE. along the banks of a mountain stream, which ends at Boricha, called the Sij Jhár, which drains the slopes of the nether hill, Dhordi Dhár and the steep sides of Dhárfaria Dungar above, to water the jungle-lands of the Ádatiána State Reserve below. The gorge of the Sij Jhár at this part branches, and cuts deeply into considerable deposits of tolerably good miliolite ; while the low-lying lands support plentiful growths of the Tanner's Cassia, (*Cassia auriculata*), and a small variety of the Gum-arabic Tree (*Acacia senegal*).

After traversing the low-lying jungle supported by the underlying miliolite deposits, a short stretch of clear land strewed with boulders of granophyre detached from the crags above, leads to the slope of a long ridge-like nether hill, called Dhordi Dhár, which stretches for about 3 furlongs from SE. by SSE. to NW. by NNW., to terminate at the

northern branch of the runnel, or Sij Jhár proper. Here, there is an excellent site for a very large quarry of the well-preserved, sound and fresh stone, capable of being easily extracted, in uniform quality and practically unlimited quantity, registered under the provisional name of a Pale Blue-grey Doleritoid Rock, as No. 120.

At the NNW. termination of Dhordi Dhár, a spur from the higher hills juts boldly downward to flank the northern gorge of the Sij Jhár, and also offers a good site for a quarry capable of yielding considerable quantities of large blocks of a particularly fresh and exceedingly tough and strong Light-grey Granophyre, of from fine to medium texture which has been registered as No. 121 on the State Collection of Geological Specimens.

Descending to the level of the Jungle Reserve below Sij Dhár, as the abovenoted spur of granophyre is named, a well-worn and fairly broad cart-track is encountered, which is stated to run past the south of Boricha and thence into the high-road from Ádatiána to Porbandar, a distance of nearly ten miles from these new quarry sites to the City Bandar. The cart-road at its Sij Dhár end continues in excellent condition, until it reaches a picturesque part, nearly a mile farther north, to gradually narrow down into a foot-path which leads upward by the side of a chasm called Bhil Jhár, and over the hills, to the shepherd's retreat in the valley below, known as Sathvirda Nes.

Bhil Jhár when viewed from the SSW. presents the centre of a converging series of mountain spurs, each of which doubtless represents the unveiled surface of an independent hypabyssal dyke. Its declivities, however, are too remote and inaccessible at the present moment to offer any inducement for the exploitation of an abundant and varied series of high-grade granophyres and felsites, here practically brought together as to a focus. These hill-spurs are most commonly buttressed below by nether hills, which offer special facilities for being quarried, and are therefore worthy of being carefully noted.

Samples were taken from only one of these nether hills, on this occasion ; namely, from the west slope of the hill on the south side of Bhil Jhár, which shall therefore be registered in this place as Bhil Dhár. The stone has been provisionally listed as a Pale Russet-grey Felsite, No. 122 ; and, although splintery, is phenomenally hard.

From Bhil Jhár, the prospecting party, with a couple of coolies carrying specimens, proceeded on foot, under the burning sun, to the site of a desiccated depression, ½ mile westward, called Doli Talav and

from thence, past the ruins of Vinjal Kot to the north, and finally, for over two miles in a westward direction over an arid limestone plain, to meet the welcome gharry at the site of old Alaswána. The drive back to camp was taken NW. by NNW. for $1\frac{1}{8}$ miles to Katwána, $\frac{3}{4}$ mile NW. to Vinjhrána, and then $3\frac{1}{4}$ miles nearly due S. to Bákharla. The whole of the country-side during the latter part of this traverse, was over land obscured by more or less miliolite-limestone, frequently fertile, well-watered and equally well cultivated. Approaching Bákharla an outcrop of laterite was noted by the roadside at the north of the village.

The following is a list of specimens added to the State Geological Collection :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
24-10-15	118	Detrital, Felsito-Miliolitic Soil of Barren Plain.	$\frac{1}{2}$ mile due E. of Bákharla
24-10-15	119	Miliolitic-Limestone. Good 2nd grade thick deposits.	Top of Sij Jhár, $1\frac{1}{5}$ miles NE. by ENE. of Boricha.
24-10-15	120	Pale Blue-grey Doleritoid Rock. Long Nether Hill. Good quarry Site.	Dhordi Dhár, $4\frac{1}{4}$ miles ENE. of Bákharla.
24-10-15	121	Light-grey Granophyre. Fine textured and very tough	Sij Dhár. Hill-spur at N. end of 120.
24-10-15	122	Pale Russet-grey Felsite. Intensely hard, but splintery.	W. slope of Nether Hill on S. side of Bhil Jhár, $4\frac{1}{4}$ miles ENE. of Bákharla.
25-10-15	123	Stone, [(Felsitic)] ? 10 ft below surface. In conglomerate, well-shaft.	Roadside, $\frac{1}{3}$ mile E. of Bákharla on way to Boricha.
26-10-15	124	Miliolite-Conglomerate. Surface of fields. Contains fragments of Laterite, etc.	$\frac{1}{4}$ mile E. of Bákharla and the surrounding country-side.

DIGEST OF DIARY.

November, 1915.

DURING the current month, meteorological conditions were not quite so favourable as might have been anticipated ; for, in spite of the cessation of the monsoon, the shortening days were characterised by shifting breezes, mainly from the north-west and occasion-

ally from the east and south-east. The temperature ranged from 67° F., to as much as 97° F., in the shade; and, for the first half of the month, little or no work could be attempted in camp after dusk, on account of annoyance from nocturnal insects.

On the 5th instant, the HAJJI ESMAIL visited the camp, for the purpose of requesting the Director to inspect his quarrying operations at Ránáwáo; to re-locate and peg out quarry-sites for the extraction of Nos. 33, 34, 38, 39, 112, 47 and 55; and to indicate the boundaries of No. 62, which had previously been recommended as an exceptionally tough and strong stone, suitable for dock and harbour construction as well as for road-metal, to the Chief Engineer of Karachi Municipality.

The request was granted;—first, in order to facilitate the work of surveying and allotting sites by the State Revenue Commissioner; and secondly to take additional notes likely to be of future use to the Geological Department. Early on the morning of the 8th instant, the Director proceeded from Camp Bákharla to Ránáwáo Station, and thence, in company with HAJJI ESMAIL and his men, by trolly, to the Ádatiána Heights.

It was found that much confusion and disappointment would result from indiscriminate quarrying on the Heights adjoining the extensive miliolite excavations; simply because many of the so-called nether hills are not in reality spurs of rock from the main massives, but merely detached boulders that have accumulated in moraine-like heaps at the base of the lofty crags. These erratic blocks of drift-material often lie deeply imbedded and high-piled upon the remnants of miliolite at the shelving limestone limit; and, in some cases, present sufficiently large quantities of one kind of stone to justify extraction on a limited scale; but the time must come, of course, when no further supplies can be expected, except by searching for the original massive on the slopes or from the crags of the high hills above. As far as possible therefore, the quarry-sites were marked for the surveyor, on the slopes of actual spurs from the mountain-massive, so as to ensure a large supply of material "true to sample."

Before quitting the Heights of Ádatiána, it was observed that a likely quarry-site which had hitherto escaped notice, existed in form of a distinct spur from the hill called Gudazali Dungar, which approached the Railway Siding. A pathway from the $1\frac{5}{8}$ mile-stone on the line, close by miliolite-quarry, No. 4 Platform leads NNE. through a deep gully to a favourable site for excavation on the slope of this nether hill,

which shall here be called Gudazali Dhár ; but a cart-track, also leads to the same site from some distance farther on the line, so as to avoid crossing the gully. The rock here, abundantly outcropping from the main mass, in the form of great spheroidal boulders, suitable for blasting, consists of a medium-textured, intensely strong and tough grey granophyre, closely resembling that of Khoria Dhár, No. 33. Samples were secured with great difficulty, in the absence of blasting, and duly registered as No. 127.

The day's work was concluded by a long drive from Ránáwáo Station over very rough ground to the sites along and by the sides of the Bordi cart-road, where large quarry sites were marked for the surveyor for the extraction of material for road-metals from Nos. 47, 55 and 62.

On the 9th instant, a brief reconnaissance was made of the SE. neighbourhood of the village of Bákharla, where it was ascertained that a wide stretch of countryside is covered by a thin deposit of miliolite-base conglomerate of compact texture, containing pebbles and grains of limonitic limestone and laterite, overlying a deep deposit of rubbly conglomerate of concretionary character, plentifully studded with rounded pellets of, apparently, laterite.

All samples collected in the field were brought to camp to be sorted, trimmed for museum or laboratory work as required, registered, and carefully packed for conveyance to head-quarters ; so that by the 12th instant arrangements were made, for a geological survey of the Barda Hill slopes, northward and WNW. from the sites of Doli Talav and Vinjal Kôt, which had previously been traversed and reported upon.

At dawn of day on the 12th inst., accompanied by a couple of coolies, a drive was taken NE. to the site of the abandoned village of Álaswána, 2¼ miles from Bákharla, and thence over tolerably level land for another mile, skirting the southern branch of the hill-stream called Álaswána Jhár. The ground hereabouts becomes increasingly rough with thickening deposits of miliolite and occluded by jungle-scrub, so that the journey for another mile to the base of the hills ESE. towards Vinjal Kot had to be continued on foot. Only about 500 yards or so of rough ground however, intervenes, to be cleared for cart-tracks ; after which a gentle, open slope leads to the foot of the hills.

On rounding the point to the N. of the gully by Vinjal Kôt, known locally as Gaikedi Jhár, the southern portion of a large hill-slope which trends from SSE. to NNW. for ¾ mile, offers a good site for quarrying operations on a large scale. This hill is named Dhedhio Dhár, and it bounds a fine expanse of grass-land belonging to the Godáhna State-

Jungle Reserve. The rock consists of a medium-textured Grey-brown Granophyre, and although much weathered superficially, was found to be extremely tough and strong and difficult to break with heavy sledge-hammers; so that, in the event of being required, it should be blasted for extraction. Enormous quantities of uniform quality are available; for, upon inspection, the entire hill, for fully ¾ mile, right up to the south side of Sárwani Wáo, consists of this useful type of stone.

Sárwani Wáo is a deep stone-lined well, with steps leading down to its brink of perennial limpid water. It is situated about 4¼ miles NE. of Bákharla, obscured by jungle-scrub and tall grasses by the side of the gully which serves to separate Dhedhio Dhár from the south spur of Málak Dhár. The vast massive of Málak Dhár sends out spurs which radiate from its summit to the N., E., S., and SW.; while its NW. moiety is flanked by a couple of long sub-parallel ridges. There are two southern spurs of considerable magnitude. The one bounding the upper bank of the mountain runnel, which subsequently emerges to form the stream called Álaswána Jhár, affords a capital site for a quarry of large dimensions, to yield an almost inexhaustible supply of big blocks of particularly fresh, sound, and practically indestructible stone, provisionally registered as a finely textured pale grey-brown granophyric felsite, which is intensely hard and tough enough to break with ordinary hammers into a sub-rectangular shingle, precisely adapted for use as a high-grade road-metal. The stone is, perhaps, slightly too vitreous to be recommended for curbs and setts; but, would unquestionably furnish ideal slabs and tiles for floors, landings, steps and other situations that are commonly subjected to severe attrition, but free from heavy crushing stress. The pleasing subdued colour of the stone moreover, which is, of course, capable of being brilliantly polished, ought to be a strong recommendation for its utilisation by ornamental masons, for the production of monuments, pedestals, columns, and even table-tops, clock-cases and the like; for, many of the great spheroidal masses may be secured in a practically flawless condition, in boulders often exceeding six feet in diameter.

Proceeding westward along the northern bank of the gully,—Alaswána Jhár, to a spot about 100 yards NW. of Sárwani Wáo, a second site for a good-sized quarry is revealed by a bold outcrop of the rook which forms the westmost, south-trending spur from Málak Dhár. Here also, the stone preserves its pristine freshness, almost unimpaired by atmospheric influences. It consists of a very tough and strong pale grey-brown granophyre of medium texture, which could be turned to

profitable account for large supplies of building-blocks and high-grade road-metal. The only drawback to opening quarries at this and the immediately foregoing sites, is that it would be somewhat difficult to make cart-tracks over the exceedingly rough ground leading from the base of the hills to the level land below. Only about one mile of pioneering work, however, would be entailed. For the rest, the existing cart-roads, *viâ* Álaswána and Bákharla, 10 miles in all to the Porbandar docks, are in tolerably good condition.

From the site just mentioned, for about five furlongs in a WNW. direction, the slopes of the westmost southern spur of Málak Dhár are approachable by old and now but little used cart-tracks. Huge, very rough and greatly weathered boulders, form a deep talus of drift material over this ground, which cannot therefore be recommended for quarrying operations; but at a spot $1\frac{3}{8}$ miles ESE. of the village of Godhána the extreme end of a SW. spur from Málak Dhár, pierces downward through the belt of jungle to the plain, forming a bold ridge, close by an old cart-track to Godhána, where a good quarry could be opened at small cost. The rock consists of a coarse-grained brown-grey granophyre, exhibiting numerous miarolitic spaces or cavities; but is so intensely tough and strong, even when considerably weathered, that only small samples could be detached with heavy sledge hammers. This stone ought to furnish ideal material for dock-work and harbour construction, where effectual resistance to intense crushing force and impacts is a *sine quâ non.*

The flat countryside intervening, from the base of Málak Dhár to the village of Godhána is more or less encrusted with deposits of coarse miliolite, and at places, with its underlying conglomeratic base, which often attains to considerable thicknesses, and lies directly upon the hypabyssal rocks of the Barda Hills and their spurs and outliers, or upon the older series of bedded-lavas which constitute the bulk of the surface lands in the Province of Káthiáwár.

The miliolite deposits, with but sundry isolated exceptions, tail down to practically a mere crust on the route from Godhána, *viâ* Katwána to Bákharla. As already observed, on approaching Bákharla from the north, the ground grows quite red; so that on the 13th, a special examination of the N. end of the village was made. It was found that the thin layer of miliolite-base compact conglomerate and its deeper beds of rubbly conglomerate with laterite inclusions, which were noted on the south side of the village, gradually dwindled down on proceeding northward and westward. At about 150 yards N. of Bákharla there is a deep stone-lined well-shaft, with its water-level at a depth of about

35 feet. Just above the water-level a ledge of black bedded-lava is exposed, while the surface surrounding the well, is formed of a thin layer of fossiliferous limestone probably of the Dwárka group overlying a rubbly conglomerate, which, at places, has entirely lost its original character by being heavily impregnated with the iron from the underlying laterite and débris of laterite long since denuded away. The red ground is thus only apparently lateritic ; but there can be no doubt that a cap of true laterite, still covers the top of the bedded-lava, 35 feet or so below, as its metamorphosed, denuded surface.

Underlying this superficial layer of pseudo-laterite, atmospheric agencies have played a curious part in dissolving and redepositing the lime of the exposed miliolite and Dwárka limestone conglomerates in form of rough, thin cakes intercalated with marly matter and heavily indued with secondary iron-oxides.

Once upon a time, iron-mines were said to be profitably worked in the neighbourhood of Bákharla. Arrangements were therefore made on the 15th instant, to visit the sites situated due W. of the village. These were found to consist of numerous small pits, each from four to six feet in diameter, sunk haphazard to varying depths in the laterised soil, but now mostly filled up by the villagers ;—doubtless for fear of accidents to cattle.

It was found that the surface of the ground commences to grow distinctly lateritic at about ½ mile due W. of Bákharla, and that traces of red earth connected this ground intermittently with the laterite at the north end of the village. The lateritic region practically extends in form of a very low hill about 2 miles long and nearly ½ mile wide at its broadest part, from E. to W. It then spreads northward and mainly westward, for about ¾ mile, past the resuscitated village of Simáni ; and evidently represents the denuded laterised cap of an elongated narrow hog-backed ridge of bedded-lava, formerly supporting remnants of Dwárka limestones and miliolite conglomerates, both holding abundant pebbles and fragments of laterite. These conglomerates, heavily impregnated with the iron from the laterite, coupled with the underlying laterite itself, which appears to be rich in separations, by metachemic reactions, of iron-ore of excellent quality, formed the material from which the natives of nearly a century gone by, kept their smeltings actively busy.

The high-road leading northward from Porbandar City, *viâ* Degám to Bhárwára, runs past, slightly to the east of the village of Simáni, and on the side of the highway at this part there is a conspicuous Hindu shrine called the Bábádeshwar Mandir. About 200 yards or so SE

of the Mandir, a 20 feet deep well-shaft, shows a superficial crust of laterite passing downward directly into decayed bedded lava. To the W. of this well, in the direction of the village of Simáni, a small elevation deposited on a base of laterite and bedded-lava, has been partially excavated; and the exposure shows thin beds of Gáj limonitic limestone and conglomerates from which fossil corals were obtained, as well as a few shells of *Pecten,* characteristic of the horizon in which they were found.

From Simáni the westward course was taken for about a mile to the parched alluvium at the extreme SE. end of the great Ger or Marsh, which extends in a north-westward direction for nearly six miles. Taking a NW. course over this pathless waste of stunted grass-ground for $\frac{3}{4}$ mile, now in an arid state, a narrow, low elevation, about $\frac{1}{4}$ mile in length, and trending from SSE. to NNW., was descried, skirting a part of the Ger-proper on its westward aspect, and bounded by a strip of cultivated land on its eastern and northern margins. This eminence, called Bhádo Dhár, was found to be capped by thin beds of obliquely laminated limestone, exhibiting colours varying from white and buff to brown, deep-purple and blackish hues. It consists of a coarse, sandy and gritty limestone, which, at its northern end overlies beds of unmistakable Gáj limonitic limestone of the Pindáralite type, but too poorly developed to be of much commercial value.

The Ger or brackish waste encroaches partially over the above-noted low-lying formations during the monsoon, leaving it thereafter in the condition of a barren area, which stretches NW., N. and NE. for about a mile in the direction of the stream to the immediate S. of the village of Bhárwára. At its southern boundary, this barren plain of alluvium is cut off effectually from the main Ger or swampy land, by a high ridge, (83 feet above the sea-level,)—which runs from ESE. to WNW. for about 5 furlongs, and calls for special notice in this place, by reason of its unique development of ornamental limonitic limestone, which shall here be specified as "Bhárwáralite." The ridge, in the form of denuded hillocks on their eastward aspect, forms a level plateau at the top, which is nearly 3 furlongs wide at its broadest part, and overlooks the Ger or Brackish-marsh on its western side. On the level of the marsh the rock appears to be composed of a pale yellow, limy conglomerate, soft and somewhat friable, overlaid by thin beds of compact limonitic limestone holding angular and rounded fragments of laterite. Superposed there comes a series of beds of earthly, limy conglomerates, alternating with beds of hard compact limonitic limestone,

available in large slabs of from a few inches to over a foot in thickness. These constitute, the newly-named Bhárwáralite-type, which differs from the Pindáralite-type of limonitic limestone, in that it assumes a uniform, fresh-looking, deep cinnamon colour, free from black spots or blemishes of any kind. With careful manipulation a very considerable yield of this desirable ornamental stone might be rescued from this original site; but it would be premature if not impossible to predict large and continuous supplies, as it is well-known that these lenticular deposits are apt to be local and to vary both in texture and quantity within very limited boundaries, since it is more than probable that they are of the nature of estuarine or sub-estuarine sediments.

From the Bhárwáralite site, a traverse of just about one mile NE. brings one to the ford of the fairly wide river which debouches westward at the Ger, and wends its serpentinous way ESE. for 3¾ miles, to gradually diminish to the dimensions of a stream and turn ENE. for another 4 miles, to be identified at its source, as Álaswána Jhár. This river, for want of a local name at Bhárwára, shall therefore be called the Álaswána Vokala. Its bed at the ford, ¼ mile SW. of Bhárwára, now almost completely dry, can scarcely fail to attract the attention of the most casual observer. It is constituted by beds of bright-yellow limonitic limestone, eroded to reveal in relief the remains of closely crowded branched corals of a greyish-white hue, and undoubtedly represents a richly coralliferous zone, co-extensive with the base of the Bhárwáralite series of Gáj (Miocene) deposits.

The coral-zone is directly overlaid by a dark-brown very sandy and gritty conglomerate, which can be traced to gradually merge into thin beds of denuded miliolite, which cap the 10 feet scarp of the Álaswána Vokala, and form the superficial foundations of the large village of Bhárwára.

From Bhárwára the return journey to the camp at Bákharla, was taken for a couple of miles ESE. along a tortuous cart-track, more or less following the north bank of the Alaswána Vokala, and, for the most part over rough miliolite ground, up to the old site of the deserted village of Rangpur. Here the bed of the river, nearly dry, was crossed, and the journey continued SE. along a fairly good cart track leading to the north side of Bákharla,—an additional distance of 2¼ miles. It was observed that the surface of the ground on approaching Bákharla from the NW., gradually lost its miliolitic character, and the presence of an abandoned well-shaft on the roadside, ⅝ mile WNW. of the village showed an outcrop of a narrow dyke of intensely black and exceedingly dense

basalt, bearing unmistakable evidence of the outcrop of bedded lavas of the Deccan-Trap Series.

It was therefore resolved, that upon the earliest opportunity, the outcropping areas of the local bedded-lavas should be carefully noted, and accordingly, on the 17th instant, a traverse of the NW. regions adjoining the village was duly made. It was discovered that practically the whole of the land lying in the NW. quadrant for a radius of fully one mile from the centre of Bákharla, consists of 'regur' soil with a small proportion of calcareous matter; and that the soil overlies a very deep layer of subsoil, composed of beds of amygdaloidal and compact lavas liberally intersected by both wide and narrow dykes and veins of dense basalt of contemporaneous origin, *i.e.* of the bedded-lava period (Cretaceous).

A series of well-shafts that were examined, were found to show the presence of a dyke of some 20 feet in width, cutting vertically through the bedded-lavas from ENE. to WSW., and traversing the countryside for more than a mile above-ground at a distance of ½ mile NW. by WNW. of Bákharla. The soil, subsoil and partially decayed amygdaloidal lava, pierced by the more enduring basalt of the dyke, yielded an ample supply of fresh potable water at a depth of about 30 feet, where it is presumed, the compact layer of the bedded-lava was encountered. An isolated well-shaft, situated ¼ mile NNW. of Bákharla, showed a thin superficial crust of miliolite, succeeded by decayed and then by fresh amygdaloidal lava to a depth of 25 feet, when water was reached upon touching the practically impervious compact zone of the lava.

The specimens collected and registered during the current month up to the 17th instant are as follows :—

Date	Registered No.	Provisional Name.	Locality and Remarks
27-10-15	125	Mottled Rock. Same dyke as No 98	Summit, Bhatwari Dhár, 5 furlongs NE by NNE. of Ránáwáo Station.
8-11-15	126	Mottled Pink and Grey Granophyre, with greenish, waxy, alteration products	Probably fallen boulders from Crags near Summit, now crowded at foot of MorChupraDungar.
8-11-15	127	Grey Granophyre. Medium textured and very tough and strong.	Gudazali Dhár; S. spur from Gudazali Dungar, opposite No. 4 Platform. Ádatiána Heights Railway.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
9-11-15	128	Compact Miliolite-Conglomerate.	Surface beds, 6 in. to 1 ft., SE. side of Bákharla Village.
9-11-15	129	Rubbly Miliolite-Conglomerate (Concretionary).	3 to 6 ft. or more, underlying 128.
12-11-15	130	Grey-brown Granophyre. Medium-textured. Very tough even when weathered. Fine large Quarry-site.	Westward slope of nether part of Dhedhia Dhár, about 4 m. NE. by ENE. of Bákharla.
12-11-15	131	Clean-washed Felsitic Sand. Recesses in bed of hill-stream.	Bed of Álaswána Jhár, on S. side of S spur of Málak Dhár.
12-11-15	132	Pale, Grey-brown Granophyric Felsite. Very hard and fairly tough.	S. slope of S. spur of Málak Dhár N side of 131.
12-11-15	133	Pale, Grey-brown Granophyre. Very fresh and tough. Good quarry-site.	100 yds NW. of Sárwani Wáo, S. spur of Málak Dhár.
12-11-15	134	Coarse Grey Granophyre. Weathered brown, but still very difficult to break with sledge-hammer.	On base of ¾ m. long, S.W. slope of Málak Dhár. Large site for series of quarries.
12-11-15	135	Coarse, Brown-grey Granophyre. Intensely hard and tough. Site for good Quarry near old cart-track.	Extreme SW. spur of Málak Dhár, 1⅝ miles ESE. of Godhána
13-11-15	136	Consolidated Shell-Sand. Dwárka Group of Beds.	Surface slabs overlying laterised. Conglomerate. N. end of Bákharla.
13-11-15	137	Intercalated Concretionary Deposit. Limy and Ferruginous.	Between 136 and 138.
13-11-15	138	Laterite and Laterised Conglomerate.	Underlying 136 at Bákharla, and 137, about 200 yds. N. of Village
13-11-15	139	Indurated Laterite.	Surface, 300 yds. N of Bákharla.
15-11-15	140	Laterised Conglomerate of Miliolite-base.	½ mile due West of Bákharla.
15-11-15	141	Laterised Miliolite	Same site. Overlying 140.
15-11-15	142	Laterite "Iron-mines" Site ..	1 m W. of Bákharla.
15-11-15	143	Laterite, Brow of rising ground ..	2 miles W. by WNW. of Bákharla

Date.	Registered No.	Provisional Name.	Locality and Remarks.
15-11-15	144	Decayed Bedded-Lava	Near bottom of 20 ft. shaft of well, 200 yds. SE. of Bábadeshwar Mandir, 3 m. WNW. of Bákharla
15-11-15	145	Laterised Conglomerate of Miliolite-base.	Same site as 142.
15-11-15	146	Fossil Coral from Gáj (Miocene), Limestone-Conglomerate. Partially overlapping Laterite.	Small excavated Mound by main roadside, opposite Bábadeshwar Mandir.
15-11-15	147	Gáj Limonitic-Limestone from Conglomerate.	Same site as 146
15-11-15	148	Dark and Light, Purple-brown Limestone, of the DwárkaGroup	OverlyingLaterite at SE. end, and Overlapping Gáj Limestone at NE end of Bhádc Dhár, $1\frac{3}{4}$ m. SW by SSW. of Bhárwára.
15-11-15	149	Gáj Limonitic-Limestone. Pindáralite type. 1 to 2 ft. thick.	Surface beyond NE. end of 148. $1\frac{1}{2}$ miles SSW. of Bhárwára.
15-11-15	150	Gáj Limonitic-Limestone. Bhárwáralite type :—Pale, uniform, cinnamon-coloured stone.	$1\frac{1}{4}$ m. SW. of Bhárwára, 83 ft. ridge, WNW. to ESE. for nearly $\frac{1}{4}$ mile alternating slabs and conglomerate.
15-11-15	151	Coralliferous, Gáj Limonitic Limestone.	Bed of Álaswána Vokala, $\frac{1}{4}$ mile SW. of Bhárwára.
15-11-15	152	Miliolite-base Conglomerate. ..	Immediately overlying 151.
15-11-15	153	Deep-black Dense Basalt. Narrow dyke through Bedded-lava.	Abandoned well-shaft, $\frac{5}{8}$ mile WNW. of Bákharla
17-11-15	154	Deep-black Dense Basalt 20 ft. wide, outcropping Dyke.	From depth of 30 ft. well, $\frac{1}{2}$ mile NW. by WNW. of Bákharla.
17-11-15	155	Amygdaloidal-Lava, exposed at surface.	From depth of 25 ft. well, $\frac{1}{4}$ mile NNW. of Bákharla.

From the foregoing records it will be gathered that, from Bákharla as a centre, the entire countryside, for a radius of over 4 miles to the W., NW., NE., E., SE. and S., has been fully investigated, thereby leaving only the SW. and a portion of the N. areas to be traversed. It was therefore arranged to cover the ground to the N. of the village during the removal of the camp to the hill-side hamlet of Godhána ; so that at dawn of day on Sunday, the 21st instant, tents were struck, and

sent by the nearest cart-route to Godhána where they duly arrived at midday. It was growing dusk, however, before the camp could be pitched and arranged for work, on account of the difficulty experienced in securing labour.

Observations during the traverse from Bákharla northward, showed that the whole of the ground between radii NW. and W., is constituted by outcropping, almost horizontally disposed beds of lava, intersected freely by dykes and veins of contemporaneous, and occasionally by larger dykes of basalt of later, (probably Eocene), origin, for a distance of about 1½ miles. Westward, the bedded-lavas are capped by laterite, while eastward, they are thinly crusted over by deposits of miliolite and miliolite-conglomerate, which increase rapidly in thickness to attain their-maximum of development, in the cradle of the Barda group of hills.

At a distance of nearly 1½ miles NW. by NNW. of Bákharla, the crossing of the now somewhat attenuated Álaswána Vokala, reveals a thin shaloid deposit of compact miliolite-base conglomerate resting directly upon the denuded and deeply-weathered flows of bedded-lava. At other adjacent exposures however, the compact slabs of miliolite conglomerate, show several feet of earthy and limy soft conglomerate, with large fragments of both miliolite and volcanic rock imbedded therein, intervening.

Pursuing the cart-track, NW. by NNW. and swerving NW. for another mile, a new small village called Berán, showed exposures of a rubbly and concretionary miliolite-base resting upon decayed bedded lava; and, with but slight variations, a similar structure of the superficial ground appeared to prevail all along the very flat plain for a couple of miles nearly due N. to the village of Wáchhora.

At Wáchhora itself, the bedded-lava, loses its crust of miliolite so that a good regur-soil, improved by limy drift from the higher lying deposits of miliolite,—around and about—, is available by localagriculturists, right away eastward for about 1½ miles on the route to Khistri. A 50 feet deep well-shaft, midway between Wáchhora and Khistri, shows fully 15 feet of soil and subsoil, above the beds of lava. At Khistri the stream which flows westward *via* Wáchhora and Bagwadar to the NE. and of the Great Ger, nearly 6 miles away, widens out into a kind of lacustrine valley where many Wild Date-Palms (*Phœnix sylvestris*), flourish by the side of ponds full of water, when all around, even the streams lie dry and parched. This expansion from a hill-fed drainage source is called the Patario Vokala; while the eminence on its southern bank on a level

with the village is pierced by a well-shaft, at the W. end of the village which shows beneath a scanty soil, about 5 feet of compact coarse miliolite, overlying 10 feet of earthy and limy miliolite-conglomerate, which, in its turn rests upon a surface of denuded and somewhat decayed bedded-lava.

Nothing of note remains to be recorded concerning the geological structure of the countryside lying to the E. of Khistri, for the $\frac{3}{4}$ mile between the latter and Godhána, save that the miliolite deposits grow fitfully deeper at the surface on approaching the higher altitudes which culminate in the cradle of the hills scarcely one mile to the E. of Godhána, a little beyond which the limestone deposits come to an abrupt limit.

On the western outskirts of the village of Godhána, there is a large, heavily lined well, down to the water-level of which a flight of stone-steps formerly led, but were afterwards cut off from the shaft of the well by a very thick wall of masonry, on account of the substructure of the ground, which, revealed by the aforesaid stone-steps, cut down through the "living-rock" shows the following peculiarities :—The surface of the ground consists of thick but fissile beds of the miliolite-base, capable of being extracted in slabs of large dimensions, but rendered coarse in texture by numerous comparatively large grains of clastic origin, probably derived from the wearing down of hypabyssal and possibly also of volcanic rocks. But, immediately underlying these compact beds, there is found to be a very thick deposit of rubbly miliolite of very dense texture, and of a ruddy-buff colour, composed of corrugated and brick-like or shaloid slabs, loosely held together with earthy and limy matter, presumably deposited by percolating carbonated waters from above. This unstable stratum, which is exposed by the excavated steps to a depth of more than ten feet, naturally gives way when bored through, so that the walls of the well-shaft had to be supported by thick masonry down to the water-level. The nature of the rock underlying the miliolite, cannot, in the absence of reliable samples taken at the time of excavation, be specified, until the immediately overlying material has been microscopically examined. It can then, of course, be determined with certitude, whether the miliolite-base rests upon a volcanic or a hypabyssal foundation, by the presence of a predominance of particles of bedded-lavas or of the equally characteristic rocks of the felsitic or granophyric group.

Camp-Station VII.—Godhana.

W. Outskirts of Village.

TENTS WERE PITCHED under the shade of a Pipal Tree, *Ficus Tsiela,* in a quiet spot about 200 yards W. of the village of Godhána on the evening of the 21st instant, and the following day was devoted to taking local observations, overhauling and packing specimens and making necessary arrangements for work in the neighbourhood.

Godhána village is favourably situated but one mile distant from the base of the great westward group of hills centered around Málak Dungar and its numerous important spurs and nether hills or ridges, which afford suitable sites for the extraction of economic stones in a variety of desirable textures and colours.

The miliolite deposits at the village itself, are denuded practically to their very base, as instanced by the well-shafts adjoining and in the immediate neighbourhood of the camp; where, upon investigation it was found that the limestone, sometimes horizontally and at others obliquely laminated, lies directly upon the bedded-lavas of the Deccan-Trap Series. On approaching the southern spurs of Málak Dungar, 1 mile ESE. of Godhána, the miliolite increases in thickness and improves in quality, being left in relief at intervals to form elongated mounds. The stone is of compact and fine texture and of a fresh pale-buff colour; but is inclined to fracture into slabs of 6 to 8 inches in thickness, rather than into blocks suitable for the building of dwelling-houses. Due E. of the village, the cradle of the hills becomes deficient, so that the miliolite decreases proportionately in thickness all along the flank of the northwardly trending nether ridge, which sends out sundry short westward spurs divided by drainage-chasms, which empty their waters towards Godhána, where a high dam has been built to form an arc at the NW. of the village, 3 furlongs in length, to serve as a reservoir, now dry, called the Hinkásar Talav.

Quarrying operations for miliolite, along the whole of the westward slopes of the nether N. and S. ridge of Málak Dungar, practically two miles, would be but of little avail, except, of course, desultorily for local needs. Indeed, upon reaching the limestone-limit, $1\frac{3}{4}$ miles NE. of Godhána, the surface of the ground bordering the banks of the emerging stream from Sij Jhár (No. 2), the miliolite base is exposed in the form of stone crowded with grains and fragments of hypabyssal rock; but,

upon continuing eastward, along the base of the slopes and spurs from the northern end of the Málak massive, to the boundary of the State at Vandhra Jhár, the superior terraces of the miliolite are left intact for a considerable thickness, amounting roughly to more than 30 feet at Vandhra Jhár, and may therefore be registered as a suitable site for future excavations if desired.

The foregoing observations were recorded during successive journeys taken mainly on foot; and, when available, by riding in gharry and bullock-cart, on the 21st, 23rd and 25th instant respectively.

It now remains to report in detail, upon the results of those traverses with reference to the hitherto unexamined economic products of the mountain massive, as follows:—

Returning to the southern spurs of Málak Dungar ESE by SE. of Godhána, the disused cart-track one mile from the village and thence for half-a-mile through the belt of scrub, (Godáhna State-Jungle Reserve), was followed to the NW. slope of a small spur, called Gured Dhár, which juts SW. from the main body of the ridge Dhorio Dhubho. Numerous large spheroids of severely weathered rock crown the summit of this eminence, which is approachable by carts at its base, and affords a fairly good site for excavation by blasting. The rock is so intensely hard and tough, that only small fragments of somewhat weathered material could be detached with great difficulty by sledge-hammers.

On examination, specimens were found to exhibit the extraordinary; and, in granophyres, unique structure known to petrologists as *orbicular*, which was first discovered in the ball-diorite or corsite of Corsica, called napoleonite in honour of the Great Emperor, but has since been found to occur in other rocks and notably in certain of the granites of Sweden and the north-west of Ireland. The rock is of a greyish colour, and, to the naked-eye shows tolerably large crystals of white felspar, each surrounded by a deep-border of blackish radially-disposed needles of probably pyroxene; so that the fractured surface calls to mind the aspect of a sclerodermic fossil coral, and, when polished, would yield rare ornamental stone of striking individuality, worthy of some special designation, which shall be given, so soon as the texture has been resolved and its mineral constituents determined under the microscope.

About 100 yards N. of the above-noted site, the slope of Dhorio Dhubho, shelves down on to the plain below, showing the truncated ends of its huge columns as a bare face of solid stone, which would instantly yield a superabundance of fresh, sound material if shattered by

Cornish Powder, Dynamite, Ripping Ammonite or other powerful explosive. This rock has been provisionally registered as a light-grey miarolitic granophyre, and is so exceptionally tough and hard as to need no recommendation on the score of strength and suitability for dock-work and road engineering operations generally, other than that which a fair trial would serve to elicit.

Passing onward and northward along the base of the long nether ridge of Málak Dungar, observations show a deep gully called the Dudedawali Jhár, $1\frac{1}{8}$ miles due E. of Godhána, which takes origin at the heights of a SW. trending spur, the summit of which is marked by upstanding columns of rock, locally known as Gabi Pir Dhar. Midway on the slope a scar on the hill-side is laid bare by a cascade during the rainy-season, which exhibits a typical columnar jointing of the rock. Lower down the gully grows deep and wide, and offers an admirable site for quarrying; but the intervening space densely overgrown with jungle-scrub, and the steep and very rugged nature of the ground before the plain with its cart-tracks can be reached, renders it, for the time being, almost inaccessible. Nevertheless, in anticipation of future developments, it may be recorded that not only does an abundance of uniform material obtain, but that the rock is capable of being readily extracted in blocks of any desired dimensions for general building purposes, while the wastage could be profitably utilised as high-grade road metal.

Petrologically, the stone has been registered as a fine-textured, strong and hard, trachytoid, light-grey granophyre. While the bulk of the material conforms to this specification, it was observed that there is a tendency in the mass to run into segregation veins and patches of quite a coarse dioritoid character, in which large and well-formed idiomorphic crystals are developed. Samples were accordingly secured for laboratory examination.

Another, but north-trending spur from Gabi Pir Dhár, extends, like a huge crescentic rampart for nearly half-a-mile forming the summit and sides of a steep slope, crowned by columnar and spheroidal semi-detached boulders, which, at a favourably sheltered part, are naturally arranged to conceal a great hollow space, in which it is rumoured that outlaws formerly took temporary refuge. This Oriental replica of the famous "Sleepin' Stane" in the Cairngorm Hills of "Bonnie Scotland," is said to afford ample accommodation for a score or more of persons at a time, and the entire formation has consequently been called "Polahpana Bhint," or Stone-hollow Wall.

The shelving wall or slope of Polahpana Bhint, runs steeply down to its base, where many immense boulders from the heights above, lie scattered in large and small heaps ; while the solid rock itself admits of being readily mined from the cart-traversed plain of jungle-growths below. It is thus clear that there is scope hereabouts, only one mile ENE. of Godhána for the excavation of many large quarries. The stone has been registered as a very tough grey granophyre of medium texture, obtainable in practically unlimited quantities, and suitable for all situations where great strength, durability and an attractive appearance are desirable.

Quite a number of small gullies and runnels drain the surface of this extensive expanse of rock, which in reality exhibits the ends of a closely set series of gigantic columns cut obliquely by denuding agencies. The waters of these streams unite to be discharged towards the S. end of the Hinkásar Talav ; but the ridge of rock continuing northward gradually slopes down to horizontality at about $1\frac{3}{4}$ miles NE. of Godhána, to be rounded from the rear by a stream-channel called the Sij Jhár, (the second of this name) which runs south-westward into the north end of the Hinkásar Talav.

It has already been observed while referring to the local distribution of the miliolite deposits of this neighbourhood, that ónly the basement beds of that series, crowded for the most part with small and large fragments of hypabyssal rocks, are in evidence at the surface of the Sij Jhár where it emerges upon the plain. After crossing this stream and ascending to the heights of the spur immediately above it, the solid rock assumes a very rough and much weathered exterior and is proportionately difficult to break without recourse to blasting. Only weathered samples could therefore be secured, and these were registered as a coarse miarolitic granophyre of a brown-grey colour. It is highly probable that the miarolitic spaces in the rock, with their incrustations of free quartz crystals and greenish and brownish decomposition products, are the results of merely superficial changes, brought about by the decay of the felspathic constituents and the redeposition from solution of the secondary silica and ferruginous colouring matter to partially occupy the vacant spaces.

Descending from this eminence, to the lower levels and taking an eastward course through dense jungle growths on a deepening miliolitic ground, a disused and very rough and rutty cart-track was followed ; and, crossing the ravine called Málak Jhár, the NW. slope of the highest summit of Málak Dungar, was found to rise steeply to its crown of con-

spicuous columns. To the immediate W. of this lofty summit a second high-hill, confusingly called Mor Chupra Dungar, rears its lesser head, and it is doubtless due to the difference subsisting between the physical bases of these two great elevations, that the great hill-like pile of boulders at their joint base, exhibits two distinct kinds of stone. The bulk of these gigantic boulders at the base are manifestly derived from the cliffs of Málak Dhár, and consist of a completely altered stone of a pale dove-colour mottled with patches of green decomposition products ;—the entire texture showing signs of being the highly metamorphosed representative of an originally coarse granophyre. The other fallen blocks, which apparently, were once *in situ*, near to the top of Mor Chupra Dungar, retain their pristine freshness, as an intensely hard, but brittle light-grey felsite which breaks with a typical conchoidal fracture, and, when greatly sunbaked, becomes quite dark, almost purple-black without losing any of its physical properties. For the present, neither of these stones can be profitably utilised, as it is a matter of some difficulty to even approach the site on foot. The lower levels, are deeply covered with indifferent miliolite, which supports a close growth of stunted Gum-Arabic Trees, *Acacia Senegal*, which at one time were utilised for burning into charcoal.

Continuing on a eastward course over an ever rising ground of deepening deposits of miliolite, for about five furlongs through thick jungle growths, towards the boundary of the State marked by the deep gully called Vandhra Jhár, a northwardly trending spur from the high ridge of Suli-na-Pani, called Vásaliyá Dhár, which slopes down to the southern bank of Vandhra Jhár, was next examined immediately above the limestone limit, and found to consist of a very fine and uniformly textured, intensely hard and yet tolerably tough stone of a fresh grey colour, practically unimpaired by prolonged exposure. Awaiting optical analysis in the laboratory, this admirable stone has been registered as a grey granophyric felsite, and although at present so remotely if not inaccessibly situated, occurs in sufficient abundance to merit special mention in this connection ; as it is anticipated that at some future time, when the deep deposits of miliolite accumulated in the gorge of Vandhra Jhár are exploited, this excellent stone, which appears to be exactly suited to the requirements of monumental masons, will also be utilised.

The bulk of the best miliolite deposits in the cradle of Vandhra Jhár, lies well within the boundaries of Porbandar State, and covers a subcircular area of about ¾ mile in diameter. Traversing the ground

of these deposits which are exposed for a depth of about 30 feet by the north scarp of Vandhra Jhár, a westward course was taken for 1$\frac{2}{?}$ miles through Navánagar territory, towards Nágka, where the boundary of Porbandar State was recrossed, by the cart-road leading almost due W. for about $\frac{3}{4}$ mile to the last named village.

Half-a-mile E. of Nágka, a newly dug well-shaft was examined and found to reveal the following succession of rocks :—5 feet of soil and whitish miliolite subsoil ; 10 feet of rubbly, indurated, russet-coloured miliolite ; 5 feet of compact blue-black basalt of the bedded-lava series. The water-level stood at 18 feet from the surface, showing a depth of two feet of water, oozing out of the arrested filtrate at the top of the practically impervious zone of compact lava.

The superficial miliolite was found to gradually thin down towards Nágka, where exposures were observed on the shallow scarped banks of the stream, called the Orio Vokala at the SE. end of the village. Here also, the bed of the stream was found to be crossed by a small dyke from ENE. to WSW., of an almost homogeneous fawn-coloured rhyolite yielding both small as well as large blocks, by reason of their sub-rectangular jointings.

Southward from Nágka, the fertile fields for a mile or more are liberally strewed with fragments of rhyolite and miliolite, while the soil itself, is, for the most part, of the nature of regur or basic volcanic mould derived from the substratum of bedded-lava. The limy constituents of the soil are unquestionably traceable to the varying depths of superficial deposits of miliolite ; while the acid volcanic rhyolites must be regarded in the light of drift material chiefly from intrusive dykes and ridges in the immediate neighbourhood.

At the small village of Bawáwao, one mile S. of Nagka which is irrigated by the Málak Vokala, and for the remaining 1$\frac{3}{8}$ miles to Godhána, nearly due S., the ground becomes increasingly rich in basic volcanic soil, from the presence quite near and occasionally at the surface of bedded-lavas and their contemporary dykes.

Specimens added to the geological collection are :—

Date	Registered No.	Provisional Name	Locality and Remarks
21-11-15	156	Miliolite-base Compact Conglomerate, resting directly on decomposed Bedded-lava.	Scarp of small stream, about $1\frac{1}{4}$ miles nearly due S. of Wachhora Village.

Date	Registered No.	Provisional Name.	Locality and Remarks.
21-11-15	157	Coarse Miliolite-Limestone. Surface stone of Well-shaft.	About 200 yds. W. of the village of Godhána.
21-11-15	158	Indurated Rubbly Miliolite. 15 ft. below surface of ground.	Same site as 157.
23-11-15	159	Pale-buff Miliolite of good quality for thick slabs.	1 mile ESE. of Godhána and ½ mile from base of hills.
23-11-15	160	Orbicular Granophyre. Spur runs S. by SSW. Accessible to carts through Godhána Jungle-Reserve.	1½ mile ESE. by SE. from Godhána. Spur from Dhorio Dhubho called Gured Dhar.
23-11-15	161	Light-grey Miarolitic Granophyre. Good site for blasting. Approachable by carts.	Sub-spur at base of Dhorio Dhubho About 100 yds north of 160
23-11-15	162	Light grey Trachytoid Granophyre Fine textured	Dudedawali Jhár, Spur from Gabi Pir Dhar, 1⅛ mile due E. of Godhána.
23-11-15	163	Coarse Segregation Rock ..	Modification of 162.
23-11-15	164	Grey Granophyre. Medium textured and very tough Extensive site for quarries.	Along base of long Northward Spur fromGabi Pir Dhár. 1 mile ENE of Godhána, called Polahpana Bhint.
25-11-15	165	Miliolite-base Stone. full of local fragments. Denuded surface	1¾ mlie NE. of Godhána, bordering W. bank of Sij Jhár.
25-11-15	166	Coarse Miarolitic Granophyre. Brown-grey and very tough.	N end of W. Nether-ridge of Málak Dungar, overlooking 165.
25-11-15	167	Highly Altered Granophyre. Main rock of Moramoid pile.	Base of NW slope of Málak Dungar.
25-11-15	168	Dark. Sunbaked Felsite. Drift from Mor Chupra Dungar.	Slightly W of 167.
25-11-15	169	Light-grey Felsite giving good conchoidal fractures.	Same site as 168
25-11-15	170	Grey Granophyric Felsite. Fine-textured. very hard and tough.	Spur from Vásaliyá Dhár. overlooking N bank of Vandhra Jhár
25-11-15	171	Miliolite-base Limestone. Russet; indurated. with lava fragments.	10 ft from surface. Well-shaft ½ mile due E. of Nágka.
25-11-15	172	Compact Basalt of Bedded-lava.	18 ft. below surface Immediately underlying 171.

Date	Registered No.	Provisional Name.	Locality and Remarks.
25-11-15	173	Fawn-coloured Rhyolite of apparently homogeneous texture	Dyke ENE. to WSW. crossing Orio Vokala at SE. end of village of Nágka

Shortly after break of day, 7-30 a.m., on the 29th inst., tents were struck at Godhána, and despatched by carts along the shortest route *viâ* Khistri and Wachhora to the town of Khámbhodar, where they arrived at 12-15 p.m., after a journey of $2\frac{3}{4}$ hours ; but tents were not pitched and arranged until 5 p.m. As most of the ground covered by the carts had already been traversed, the route to Khámbhodar, taken by the Director, was arranged to pass over entirely new ground, partly on foot, as follows :—

From Godhána the northward cart-road was followed for about $\frac{5}{8}$ mile, and a prolonged halt was called for the purpose of examining the geological structure of a long, low ridge which was ascertained to run approximately S. by SSE. to N. by NNW. from a spot 3 furlongs NE. by NNE. of Khistri for a distance of $4\frac{1}{2}$ furlongs. The ridge is about 1 furlong broad at its S. end, but gradually diminishes in width as it approaches its N. termination. Observations show that the rock of this prominent dyke consists of an apparently uniform-textured, compact and apparently homogeneous sub-vitreous rock, exhibiting a dominant fawn-colour. The mass is vertically and transversely jointed to disintegrate on weathering at the surface, into a sub-rectangular small shingle at its sides and into larger blocks,—sometimes 2 to 3 feet across,—towards the central portion of the mass. These large blocks when broken, show a tendency to spheroidal shrinkage, so that they do not possess any pronounced "rift," or property whereby large flat surfaces are capable of being readily secured ; but break with a conchoidal fracture, and frequently become splintery by the unseen joints or lines of weakness developed in divers directions. The stone however, is easily workable with ordinary hammers, into small building-blocks ; while the wastage or rubble of sub-rectangular shingle, would furnish ideal clean-keeping material for placement between railroad sleepers ; but, although unquestionably superior to rubbly, indurated-mliolite or consolidated shell-sand as a road-metal, the material by reason of its sub-vitreous nature, cannot of course, be classed by the side of even felsite, for macadamising permanent highways.

Capable of receiving a high polish, the delicate fawn-colour of the stone ought to find favour for its employment on a large scale by manufacturers of fancy-tiles, clock-cases and other small ornaments. Upon investigation, however, it has been found that the original colour of the fresh-stone from the lower depths of the dyke is of a very pleasing grey hue ; but that this becomes changed into deeper and lighter fawns, shading off into purples and browns and sometimes minutely mottled with specks of olive, according to the degree of sun-baking to which the stone has been subjected season after season. These changes, doubtless due to a ternating monsoon and hot-weather conditions, however, do not appear to have caused any decay or decomposition, except at the very surface, to the general texture of the material ; which, if anything, is rendered a trifle harder by the alteration.

Towards the edges of the intrusive mass, found in contact with the bedded-lavas through which it has been forced, the rock acquires a darker colour and becomes indurated and glassy and frequently exhibits a closely striated or flow structure, which coupled with its lighter colour and other physical properties, serves to place it among the group of acid volcanic lavas called "rhyolite." This banded-variety, at and near the zone of contact-metamorphism, outcrops at the extreme SW. end of the ridge, 3 furlongs NNW. of Khistri.

A small stream skirting the SE. side of the rhyolitic ridge, wends its way SW. to Khistri valley, and its dry bed and scarped banks, at this time of the year, shows an inch or two of compact miliolite-base stone, overlying a foot or so of rubbly miliolite conglomerate full of lava-pebbles, overlying the denuded subsoil of the main-body of bedded-lavas below.

Passing north-eastward to the ford across the stream, Málak Vokala, at the village of Báwawáo, and thence, along the N. bank of the water-course, a small, 30 feet wide, dyke of dark fawn-coloured trachytoid rhyolite of uniform texture was located, about 300 yards W. by WNW. of Báwawáo taking a direction from ESE. to WNW., and evidently forming a branch of the main dyke of rhyolite which outcrops to the NE. of Khistri, terminates above-ground $4\frac{1}{2}$ furlongs farther north, and re-appears in form of a 100-yards-wide, low ridge, just $\frac{1}{2}$ mile E. of Báwawao, called Páriá Dhár.

Páriá Dhár itself, runs almost due N. for fully $\frac{1}{4}$ mile. It is constituted by a particularly fresh trachytoid rhyolite of compact, uniform texture, and a pleasing grey colour tinged with purple—the purple tint being manifestly superinduced by sunbaking. Ample sound blocks of

tolerably large dimensions are available ; but these, like all other rhyolites, are prone to break up into sizes not much in excess of an ordinary brick. Such material has been extensively used for building as well as for paving in the United States, with entire satisfaction. At the southern base of Páriá Dhár, a zone of contact metamorphism is exposed, where the stone becomes almost purple-black in colour, splintery and glassy and frequently finely banded.

Still farther south, the ground is thickly strewed, over a considerable area, with weathered-out spheroids of dense blue-black basalt, each bearing numerous very thin shells, concentrically attached, of decomposed earthy iron-ore. The nuclei of these spheroids preserve their pristine freshness ; while all that remains of the interstitial stone which once held the spheroids together in columnar series has vanished into soil, save the thin shells of hard, brittle, oxidised matter. The spheroids vary in size from about 3 inches or less to 6 inches and over in diameter ; and, from similar occurrences in other parts of the Province, it is probable that they once formed an integral part of a great basic dyke of volcanic matter extruded immediately prior to the cessation of eruptions in the Eocene era.

The specimens gathered during the above-noted traverse have been registered as follows :—

Date.	Registered No.	Provisional Name	Locality and Remarks.
29-11-15	174	Pale Fawn-Coloured Rhyolite, with flecks of white (felspar ?).	S. end of S by SSE to N. by NNW. Ridge 3 furlongs NE by NNE. of Khistri.
29-11-15	175	Purple-fawn Rhyolite with mottling specks of olive hue	Altered variety of 174, from the same site
29-11-15	176	Indurated Dark-brown Banded Rhyolite Contact zone of Dyke	SW. edge of Ridge, 174.
29-11-15	177	Compact Miliolite-base Stone. Denuded to only a very thin layer.	Bank-top of small stream, 100 yards E. of 174.
29-11-15	178	Rubbly Miliolite-Conglomerate .	Immediately underlying 177.
29-11-15	179	Dark, Fawn-coloured, Trachytoid Rhyolite of uniform texture.	300 yards W. by WNW. of Báwawáo. Dyke runs ESE. to WNW.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
29-11-15	180	Grey Rhyolite. Trachytoid and tinged with Purple Uniform texture	Páriá Dhár. ½ mile E of village of Báwawáo
29-11-15	181	Dark, Indurated, Banded Rhyolite	Contact-zone at S base of 180
29-11-15	182	Basalt Spheroids, weathered out of Later-series Dyke	S base of Páriá Dhár, S of Rhyolite Contact-zone

DIGEST OF DIARY.

December, 1915.

Camp-Station VIII.—Khambhodar.

SE. Outskirts of the Town.

TENTS HAVING BEEN PITCHED on a satisfactory level patch of ground, shaded by a large clump of well-grown Pipal-trees, on the SE. outskirts of the town, adjoining the northern bank of the Paisani Nuddy, a general geological reconnaissance was made on foot over the countryside, for a radius of about a mile from the centre of Khámbhodar on the 1st instant.

It was found, mainly by observation of the exposures eroded by the Paisani Nuddy, now nearly dry, that the fast thinning crust of miliolite noted at Nágka gradually dwindles down westward, to be represented on reaching the State-boundary near the old-site of Temri and the new village of Nutwarpura,—so called in honour of H. H. the present minor RÁNÁ SAHEB OF PORBANDAR,—by more or less of drift-material, sometimes deeply imbedded in the thick stratum of bedded-lava soil and subsoil. The abundant 'regur', seasoned with a fair proportion of lime from the miliolite-drift, and perchance a trifle of felsitic earth washed down from the Barda Highlands, barely 5 miles to the east, affords excellent, easily cultivable ground for the cotton-grower or cereal agriculturist.

The clerk of the Department, as Camp-manager, having been despatched to headquarters, with work for the mechanic, and to

attend to monthly accounts, the work in camp was directed to the trimming, registration and packing of the numerous specimens secured for the State Geological Collection ; to the compilation of part of the Second Quarterly Report, and the colouring of the Geological Chart. A second journey to Porbandar was also necessitated through the absence without leave, of the peon who was left in charge of the Bungalow. An important excursion was thereafter made on the 7th inst., the results of which were recorded as follows :—

By draining the north-western slopes of Málak Dungar, to emerge at the base of the hills as Málak Jhár, and thence westward past Báwawao as Málak Vokala to form a confluence with a lesser stream from the heights of Vandhra Jhár, at the village of Rojhra in Navánagar State, the Paisani Nuddy thenceforward swerves south-westward to widen out into a low-terraced valley immediately to the south of Khámbhodar, to finally debouch into the Ger or brackish-marsh, about a mile SW. of Kindarkhera as a diminished stream. As a very rapid and turbulent watercourse during the monsoons, the river has frequently channelled its course deeply at many places, thereby revealing scarped exposures of 10, 15 and even over 20 feet, which help, in no small measure, to disclose the geological structure of the superficial formations for a distance from east to west of close upon nine miles. In traversing a course along the banks of the Paisani Nuddy from Khámbhodar, *viá* Nutwarpura and the site of abandoned Temri to Rojhra in Navánagar State, the ground presented a fair and fertile aspect, by reason of its deeply decayed superficial bedded-lavas, strewed with miliolite-drift, with signs of but a few minor dykes of decomposed basalt, and sundry exposures of the dry-bed of the river, showing the surface of the bedded-lavas as either rudely columnar or polyhedrally jointed.

At Rojhra, a familiar outcrop of lithiodal rhyolite with a narrow (2 to 3 feet) differentiation of black, glassy obsidian was inspected, with a view to instructing the members of the excursion party what to look for, while subsequently traversing similar ground a little later on. The Rojhra rhyolite unfortunately vanishes underground in an eastward direction ; but doubtless forms part of a WNW. diverticulum from the rhyolitic ridge noted in last month's report, as Páriá Dhár.

Continuing from Rojhra ENE. along the cart-road to Nágka, a halt was called ½ m. SW. by WSW. of the last-named village, in crossing over a barren rocky ridge plentifully strewed with large fragments of ruddy-brown sub-angular shingle. Bearings were taken, and it was found that this ridge, with but a couple of small interruptions, is in

direct continuity with, and precisely similar in all essentials, with the rhyolitic ridge of Páriá Dhár. Samples nevertheless were taken, and a keen outlook kept for the anticipated outcrop of a band of obsidian as a few stray pieces of that rock, in appearance like that of lumps of coal, had been detected among the shingly débris lying on the ridge.

A broad offshoot of rhyolite from the practically N. and S. ridge, was traced taking a WNW. direction for about three furlongs above-ground and to then disappear below; but the rhyolite was thereafter found to reappear a mile and-a-quarter farther along in Navanagar State; this time, however, in the semblance and with all the structural characteristics of a sheet or lava-flow.

While tracking the northward course of the main rhyolitic dyke from ½ mile WSW. of Nágka to its apparent termination 500 yards W. by WNW. of the village, it was noticed that the stray fragments of obsidian were met with, amid the superficial shingle of the dyke, more frequently; and it was therefore expected that an outcrop thereof would soon be detected. In swerving slightly eastward, the dyke is eroded to its very centre by the channel of the Orio Vokala, and affords thereby an exceptionally good view of its sub-vertical columnar jointing of which a photograph was taken. It is thereafter obscured by a deep layer of soil; but manifestly narrows down, to be re-exposed in a remarkable manner by the erosion of a tributary nala to the Orio Vokala, some 350 yards WNW. of Nágka.

At this part, which is evidently the termination or forked termination of the dyke, the banded character of the rhyolite becomes extremely perfect, being differentiated into zones of fissile black obsidian, intercalated with much jointed slabs of highly indurated lithoidal rhyolite; the entire mass being characteristically contorted by its flow through a sinuous fissure. Samples from each part of this excellent exposure, together with portions of the country-rock (reticularly-jointed bedded-lava), near the zone of contact were secured for microscopical examination.

After a general survey of the ground for a radius of nearly a mile to the N., NE and NW. of Nágka up to the surrounding boundaries of the State, which revealed a superfices of bedded-lavas, more or less incrusted with deposits of miliolite, the NW. cart-road was followed beyond the State limit to Háthla in Navanagar territory, and from thence, crossing the boundary ¾ mile WNW., and ½ mile farther in the same direction, the village of Kunwadar was reached. From Kunwadar, southward for 3¾ miles back to the camp at Khámbhodar, the country

presents a wide stretch of level plain composed essentially of deep fertile soil derived from the bedded-lavas below; the only noteworthy observation made, being the occurrence of a dyke of excessively dense, deep-black basalt, varying from 10 to 20 feet or so in width, and level with the surface of the land, which takes a course from E. to W., slightly trending WNW. Along this dyke, several well-shafts, each yielding an abundant supply of limpid water at a depth of some 20 feet, were sunk, and the dyke itself was said by local labourers to extend for fully 6 miles westward right up to the village of Sisli, and beyond.

Specimens added to the State Geological Collection are duly registered as follows:—

Date	Registered No.	Provisional Name	Locality and Remarks
1-12-15	183	Miliolite-Drift, thickly strewed on surface and deeply imbedded in soil	Between Khámbhodar and Nutwarpura
7-12-15	184	Lithoidal Rhyolite with flow-structure. Pale brown-grey and sunbaked	$\frac{3}{8}$ mile W. by WSW. of Nágka. Low ridge. Sloping surface, edge of dyke from ESE. to WNW.
7-12-15	185	Lithoidal Rhyolite. Sunbaked, pale brown-grey. Uniform texture	Centre of Dyke 184. Large blocks available by blasting
7-12-15	186	Lithoidal Rhyolite. Sunbaked purplish. 20 ft. high sloping dyke	$\frac{3}{4}$ m. SW. of Nágka. Centre of dyke. Large, uniform-textured blocks
7-12-15	187	Lithoidal Rhyolite. Nucleus of weathered-out spheroid	Slope of dyke, 186. To show atmospheric alteration
7-12-15	188	Banded Rhyolite. Sunbaked	Base of dyke. $\frac{1}{2}$ m. WSW. of Nágka
7-12-15	189	Banded Rhyolite. Banding due to spheroidal structure of columns	Large columns exposed by erosion. Stream, 500 yds. W. by WNW. of Nágka
7-12-15	190	Black Obsidian. Terminal part of dyke	Exposed by erosion of nala. 350 yds. WNW. of Nágka
7-12-15	191	Indurated Rhyolite	Intercalated with 190
7-12-15	192	Indurated Rhyolite	Contact. Underlying 190
7-12-15	193	Bedded-lava, reticularly jointed. Altered by contact with Obsidian	Contact zone below 190 and 192
7-12-15	194	Dense, Deep-black Basalt. Dyke runs E. to W. to near Sisli	Well-shaft, 20 ft. deep. $\frac{1}{4}$ mile S. of Kunwadar

Enforced camping at Khámbhodar, during which this report was written, was occasioned by break down of the gharry, due to prolonged driving over very rough ground.

Tents were struck at Khámbhodar at 7-30 a.m. on the 12th inst., and the journey northward taken to Sodhána, where considerable delays were occasioned in finding a suitable site for the camp and getting the requisite help; so that it was past 5 p.m. before tents were pitched in readiness for occupation.

Proceeding along the NNW. made-road for a distance of approximately $3\frac{3}{4}$ miles to the village of Majiwána, frequent stoppages were made for the purpose of examining cuttings and natural exposures by the way;—and the following entries were made in the field-book:—The ground from Khámbhodar, which consists essentially of a deep layer of decayed bedded-lava tempered with more or less miliolite drift, grows gradually less calcareous farther and farther north simultaneously with an almost imperceptible rise in the level of the land, when the miliolite débris practically disappears; so that the well-cultivated cotton and other grounds on reaching the highest level of 102 feet above datum, at $1\frac{5}{8}$ miles NNW. of Khámbhodar, is of the nature of 'regur' or pure volcanic soil of a pronouncedly basic character. The depth of this fertile soil varies from 3 to over 6 feet; while the subsoil averages about ten feet or so, before the zones of sound bedded-lava are reached Subordinate dykes and veins, much decayed, but easily detectable, by reason of their closely-set transverse joints, appear on a level with the surface every here and there. They are probably contemporaneous structures, but not of sufficient importance, either to the scientific inquirer or rural economist to merit further notice.

At the highest level, which spreads out E. and W. in semblance of a low ridge, $1\frac{5}{8}$ miles NNW. of Khámbhodar, there is a road-side Dharamsála, at the back of which a deep well-shaft has been sunk, which shows from 10 to 12 feet of soil and subsoil, followed by beds of lava to the total depth, from the surface, of 66 feet;—the present water-level standing at 60 feet from the top of the well. This, and other records of a like character, are, and will be noted, as having an important bearing on the underground water-supply of a countryside chiefly constituted by accumulations of bedded-lavas.

There is a decided declivity proclaiming the ridge-like character of the ground on its northern aspect, and this is succeeded by a gentle rise about 5 furlongs farther on the NNW. main-road, which thereafter slopes gradually downward to a level of 65 feet above the sea at Máji-

wána, where observations were taken on the north side of the village at a succession of well-shafts, reputed to yield unfailing supplies of good drinking-water. These well-shafts were found to yield plenty of water at a mean depth of 40 feet from the surface, with about 6 feet of water below that level. They were further noticed to be sunk on the line of an almost vertical dyke of very dense, deep black basalt, running from E. by ESE. to W. by WNW., and thus verified the statement that the dyke is continuous with that previously observed immediately to the south of Kunwádar nearly 2 miles farther east, and rumoured to rise intermittently and then continuously above ground as far as Sisli and beyond.

This Kunwádar-Májiwána-Sisli dyke, as it may be specified, varies considerably in width ;—from 10 to 30 feet or more. It is typical of the narrower series of dykes of the later (Eocene) period of eruptions from the Barda focus, in having its closely columnar joints, transversely divided by intense lateral compression, to give birth, upon weathering, to a sub-rectangular or polyhedral medium-sized shingle of from 3 to 6 inches or so across each section. Prolonged atmospheric reactions, further reveal the pre-existence of spheroidal shrinkages in each polyhedron, which can thus be resolved by a hammer into an excessively hard subspherical nucleus, surrounded by concentric shells and interstitial altered and decomposed matter. In this condition, the excavated dyke-rock ought to furnish excellent ready-made macadamising material for roadways, vastly superior to hard limestone rubble ; but, of course, not so durable nor adapted for heavy-traffic high-roads, as ordinarily fresh granophyre.

When the polyhedra, according to sizes, are simply smashed into two or more pieces, the practically fresh and sound nuclei, need not be freed from the shattered, iron-bearing shells nor crumbled, decomposed interstitial earth ; for these will be found useful to serve as packing for the "metal", which, when watered and rolled, would instantly settle down into a consolidated level surface, capable of resisting ordinary wear and tear, with but occasional repairs, for many,—say 3 to 6 years. It was observed that some of this material, presumably from the well shaft excavations of Májiwána, has been desultorily used on the adjacent high-road, which has thus been unconsciously maintained, at places, in excellent condition at small cost ; but, alas ! it was also observed that the metal at other places was largely adulterated by semi-decomposed bedded-lavas from the subsoil of their immediate surroundings.

Special attention is being devoted, whilst traversing the bedded-lava regions of the State, to the outcrop and course of the dykes likely

to have a direct bearing on the artificial irrigation of the land. In connection with this subject and particularly with the choice of suitable sites for well-sinking, FEDDEN in a footnote at page 33, of his Memoir on the Geology of Káthiáwár, writes :—" It was observed that the agriculturists sink their irrigation wells along the dykes, tracing out their course with great assiduity ; they are almost invariably rewarded by the wells yielding water at a depth within 15 to 20 feet of the surface. In some instances it would appear that the joints and cracks in the dyke-rock communicate with some deep-seated water-bed ; in other cases the dykes seem to wall up, and keep in on one side, the water of the adjoining strata."

Samples of dyke-rocks, will in future be taken with a view to determine whether there are any features that may serve to distinguish the later from the older series of eruptions, or to point to the presence of a utilisable underground water-supply.

Onward from Májiwána to Sodhána, little or nothing of note could be observed beyond a continuity of sameness in deep fertile bedded-lava soil. The main-roadway takes a dip to form a level-crossing over the bed of the wide Wartu River, which is here obscured by a deposit, of natural riprap ; while the well-shafts that were peeped into *en route*, right up to the town of Sodhána disclosed naught beyond deep soil, still deeper subsoil and beds of lava too far down to be accessible for sample collecting, but plainly seen to be constituted by successive zones of amygdaloidal and compact lavas.

Camp-Station IX.—Sodhana.

Small Field, 150 yards SSE. of the Town.

AFTER CONSIDERABLE DELAYS, occasioned by hunting in vain for a good camping site, tents were pitched on the 12th instant in a small uncultivated field partially hedged in by thick growths of the Milk-bush, *Euphorbia Tirucalli*, and the equally objectionable Prickly Pear, *Opuntia Dillenii*. It was therefore dark before things could be brought into good order.

Sodhána was selected, after much demur, as the most suitable centre for geological operations in this remote and awkwardly situated portion of the Porbandar State ; inasmuch as the land to eastward stretches in form of a comparatively narrow cul-de-sac into the adjoin-

ing State of Navánagar; and, from the previous experience of the writer, is not likely to yield any specially noteworthy results other than those in confirmation of the fertility of its well-watered soil and agricultural resources.

To traverse this secluded stretch of land speedily yet satisfactorily, arrangements were made for the following long excursion on the 14th instant :—A southward course was taken and a stoppage made about ½ mile from Sodhána Town, where a fairly deep layer of detrital soil had been desultorily removed for the purpose of quarrying out blocks of coarse, but compact rubbly-miliolite for local use. The miliolite was found to be denuded down to strata of barely more than three feet, resting upon decayed bedded-lava; while the wide plain above remained uncultivated on account of being periodically flooded by overflows from the River Wartu, ½ mile farther south. The fertile ground however, is over-run by growths of Tanner's Cassia and Wild Indigo plants.

Following the cart-track to the ford across the River Wartu, 1⅛ miles SSE. of Sodhána, the broad bed, (150 yards across), of the river which runs E. and W. at this part, was found bordered by long and deep pools of water, overshadowed by scarps of bedded-lava soil, from 10 to 12 feet high, affording a good feeding ground for many mallards, shovellers, teal and other birds. The river bed of decayed bedded-lava was thickly covered by enormous quantities of sand of a very mixed character with patches of pebbles and riprap.

Skirting the south bank, the journey was continued eastward and then ENE. to the village of Morana, where an examination of well-shafts showed some 4 feet of solid miliolite at the surface, overlying rubbly-miliolite and miliolite-conglomerate for another 8 feet ;—the whole resting upon a substratum of decayed bedded-lava, with the underground water-level at 17 feet below the surface.

From Morána-village, a walk northward for about 350 yards, redisclosed the channel of the River Wartu; but this time its bed was found to be bare, and upon close examination, showed an exceedingly decayed zone of amygdaloidal lava, covered by a partially denuded but still fairly fresh zone of compact, basalt, closely cleaved at places and generally exhibiting a sub-columnar or small cuboidal structure. Careful scrutiny of the zone of contact between the amygdaloidal and its superjacent compact lava, revealed a thin selvage adherent to the latter of *tachylyte*, a goodly portion of which had been altered by devitrification into a lithoidal condition.

Continuing ENE. for two miles to Párewára, the River Wartu, takes a northward crescentic bend, and, save for its steep N. scarp, capped by deposits of miliolite, no further structure was observable, as the channel of the steam became increasingly filled with water. The picturesque village of Bhomiawadar, perched on the high brow of the northern scarp of the watercourse, five furlongs farther to the NE. from Párewára, could only be viewed from across the river, as the declivity to the former ford directly opposite to the village was dangerously steep; so that a roundabout détour had to be taken to approach the ford some 500 yards farther east.

At Bhomiawadar, both banks of the River Wartu exhibited scarps of about 20 feet high, with from two to three feet of coarse but compact miliolite at the top, forming the foundation of the village. This stratum overlies a very variable, yet considerable thickness of false-bedded gravelly and pebbly basement indued with limy matter, which in its turn rests upon a coarse rubbly or brecciated conglomerate, directly overlying partially weathered beds of lava which form the floor of the shallow stream.

A particularly uninteresting drive was taken NE. for fully three miles to the village of Simar, where, as at Bákharla, there appears to be an excellent State Bungalow, monopolised as Police-quarters. During the drive it was found that the undenuded miliolite forms a band of insignificant width, surrounding the course of the River Wartu, but rapidly diminishes to nil northward; so that at less than half-a-mile NE of Bhomiawadar, not a vestige of calcareous rock remains. Well-shafts hereabouts, show the water-level at a depth of 15 feet, through 12 feet of soil and 3 feet of subsoil. Yet half-a-mile farther NE. the ground assumes the aspect of a rock-plain, with but little soil;—the country-rock being altogether of the nature of decaying bedded-lava, reticularly jointed. Only one dyke of any consequence was found, consisting of a dense blue-black basalt, some 30 feet wide, running from SSE. by SE. to NNW. by NW., about 500 yards SSW. of Simar. Such dykes are marked on the map by thin red lines.

Reticular or polyhedral jointing, first so called by the writer, is in reality but a modification of the columnar form so generally recognised among rocks of igneous origin. It arises manifestly by the abbreviation of the transverse intervals, which usually divide the master-joints of the columns in rocks of both deep-seated and superficial consolidation. The reticulation may be on a minute, even microscopic scale, or may divide the mass into polyhedra of an inch or two up to as much as a

foot or so across. When developed on a larger scale, the reticular merges into the evidently columnar style of jointing.

Now, practically the whole of the countryside between Bhomia-wadar and Simar,—which rises in its level so noticeably as to affect the vegetation, to wit, by the frequent appearance of the Bastard-Teak, *Butea frondosa*, now becoming conspicuous by reason of its flaming vermilion blooms,—consists of bedded-lavas, more or less reticularly jointed, and this facies continues to prevail from Simar as a centre to all points of the compass cut by the boundaries of the State, with the exception of sporadic eminences capped by insignificant deposits of miliolite or the miliolite-base that have escaped denudation. At certain places, the reticulation, notably ½ mile SW. of Rojhiwára, becomes so fine, that, when weathered sufficiently, the country-rock disintegrates into small grains which ultimately grow powdery. At other parts, but a few yards distant, the polyhedra and their nuclear spheroids, attain to as much as four to six or more inches across. When the weather is dry and the roadway is covered with a six-inch deep layer of the broken-down granular lava, it tends to impede vehicular traffic ; while, when the naturally-broken shingle exceeds 1½ or 2 inches in diameter, the roadway is apt to be troublesomely rough.

Whether amygdaloidal or compact, the bedded-lavas throughout the region traversed are of this reticular character, and when not too much decomposed, admit of being very readily crushed to instantly yield an abundant supply of excellent hard-wearing " metal " suitable for macadamising or for top-dressings with or without tarring, provided always that the reticular meshes, so to speak, yield shingle of the desired gauge for the work in hand ; and also that amygdaloidal shingle, for obvious reasons, is rejected.

On the way back to camp from Rojhiwára, *viá* Iswaria and Bhomia-wadar along the westward cart-road leading to Adwána, a great rock-plain of reticulated bedded-lava prevailed ;—sometimes amygdaloidal, but more often compact in character. On reaching a spot one mile SE. by SSE. of Adwána, a long low ridge trending SSE. to NNW. of dark-black basaltic dyke-rock, with characteristic transverse jointings was carefully noted for future and further investigation.

At 8-30 a.m. on the 16th instant, the traverse of the countryside above-noted was resumed by a rapid drive across the substantial stone bridge that spans the Sorti Nuddy immediately N. of the town of Sodhána, and thence for 1¼ miles NNE. to Adwána-town built upon the SE. terminal eminence of a ridge of bedded-lava, which runs, with interruptions,

to the NW. for about a mile. The ground between Sodhána and Adwána, was observed by peeps into well-shafts to be essentially composed of bedded-lavas very deeply decayed ;—the soil at some places reaching down almost to the mean water-level of 20 feet below the surface.

By re-crossing the Sorti stream ¼ mile SE. of Adwána and continuing for another 3 furlongs, the dyke already noticed to form a low, long ridge one mile SE. by SSE. of the town was traced to remain exposed on the surface, and then to vanish ; but it was subsequently found outcropping about ¾ mile NNW. by NW. of Adwána on the roadside, and was again detected 33 feet below the surface in a well-shaft on the E. side of the roadway leading to Nagaria in Navánagar State, about 2 miles still in the same direction, NNW. by NW. of Adwána

About 2 miles E. by ENE. of Adwána, the ground becomes perceptibly hilly, and consists of a wide rock-plain, sparingly cultivated, of bedded-lava reticularly jointed, to yield an abundance of surface shingle, sometimes fairly fresh, and capable of being gathered readily and screened to yield abundant supplies of naturally-made road-metal and road-dressing material, quite good and durable enough for the proper maintenance of all the local roadways, at a minimum of cost. Right up to the State boundary in this direction, for fully 3 furlongs, the same characteristics prevail ; while northward, after crossing a deep ravine, and traversing about 2 miles of more or less fertile ground to the surrounding boundaries east of the Sorti Nuddy, which runs from Adwána practically due north, nothing beyond bedded-lavas with but a few insignificant dykes could be detected.

Returning to Adwána, across the Sorti stream, hilly ground, capped with the remnants of a deposit of miliolite was encountered forming a narrow irregular eminence ½ mile due N. of the town. The material from this small hill is not of sufficiently good quality for building blocks, but affords a fair supply for burning into lime, for local use.

About 150 yards west of the miliolite-capped mound, the NW. roadway from Adwána is flanked on its westward aspect by a high ridge of reticularly-jointed lava, which runs SE. to Adwána and NW. to a summit of 124 feet above the sea-level, forming an eminence of nearly one mile long by about three furlongs at its widest part. The bedded-lava of which this is composed consists of a very tough and but slightly amygdaloidal material, from which an abundant polyhedral shingle of from ½ to 2 inches in diameter is shed upon its slopes, and could therefore be economised by use as road-metal of fair quality for local wants. On the eastward base of this ridge the long NW. by NNW. to SE. by

SSE. dyke already alluded to, takes a somewhat sinuous course above ground, to vanish, and then reappear, 33 feet below the surface, in an old well-shaft 2 miles NW. by NNW. of Adwána.

Cutting westward along agricultural cart-tracks, the arable land about 500 yards due W. of the well-shaft just noted was found to be strewed with large fragments of impure milk-white rhombohedral calcite ;—the relics of a small superficial vein through the bedded-lava, now utterly destroyed. This vein probably ran westward to a spot $1\frac{3}{8}$ miles N. by NNW. of the resuscitated village of Bhatakri, where a small outcrop still remains untouched.

The country-side around and about this calcite vein, approximately centered by a small isolated mound of miliolite, about $1\frac{5}{8}$ miles NNE. of Bhatakri, appears to be somewhat siliceous, being strewed with fragments of veins and geodes of onyx, chalcedony and quartz, frequently intergrown with calcareous matter. These fragments might perhaps be utilised by thrifty villagers for fancy-button making.

On Saturday, the 18th inst., tents were struck at 8 a.m., and the camp was transferred to Morwára, where no help was afforded by the resident Tapedhar, so that it was past 6 p.m. before things could be got into working order in a hedged-in piece of ground about 100 yards to the ESE. of the town.

The journey from Sodhána to Morwára was arranged to cover a maximum of hitherto untraversed ground as follows :—The south-western cart-road was traversed for a distance of $1\frac{3}{4}$ miles, over deep fertile bedded-lava soil with the exception of a small patch of about 3 furlongs in width in the vicinity of Sodhána, which exhibited a mere crust of miliolite, covered by a foot or so of alluvium deposited by periodical overflows of the river Wartu. After crossing the gravelly and pebbly bed of the Wartu, a southward course for nearly 3 furlongs was taken to the town of Fatána, where the underground water-level at a mean depth of 20 feet, entirely through bedded-lavas was observed by the examination of local well-shafts.

It was noticed that the compact zone of the bedded-lava superficially exposed, reached down to a considerable depth, and, upon reaching the SE. quarter of the town due advantage appears to have long since been taken of this circumstance, by the excavation of small pit-quarries to supply building-stone for local wants, inasmuch as no miliolite occurs in the neighbourhood. The black-stone quarries showed exposures, under only a very little subsoil, of tolerably fresh, and fairly tough, sound, compact stone, in vertically jointed columns, capable of yielding

good-sized building-blocks, setts and road-metal in abundance ; but the excavations being of the nature of pits in level land, there must always be the disadvantage of water-logging and the premature rotting of the stone from the presence of an excess of quarry-water.

From Fatána the WNW. cart-road for $1\frac{1}{2}$ miles, to Singra, traversrs a richly fertile and well-watered country side of deep bedded-lava soil. Singra with its conspicuous "Derá" or Temple, is situated on an eminence of tough, compact, slightly-amygdaloidal lava, of which a good sample was obtained from near the bottom of a well-shaft, 100 yards WNW. of the Temple.

Proceeding along the cart-road WSW. for $1\frac{3}{4}$ miles to Sisli, brief halts were called, and detours made, first, about $\frac{1}{2}$ mile SSW. of Singra, where the hilly undulating rocky surface, was found to be composed of a tough, slightly amygdaloidal lava, reticularly jointed, and liberally strewed with shingle of all sizes up to about 4 inches across, in a condition fresh enough to be utilised for local road improvements, by being screened and occasionally broken. At about 500 yards E. of Sisli, the great dyke, already traced as trending thence from S. of Kunwádar and *viá* Majiwána, was carefully examined. At the spot just noted, a small well-shaft, yielding but a poor supply of water at a depth of 25 feet from the surface, the dyke measured about 30 feet in width ; but showed unmistakable signs of excessive lateral compression, inasmuch as the dense black basalt of which it is composed, exhibited such perfect cleavage, that the material when slightly weathered, was found to be transversely split into thin flakes, most of them much less than $\frac{1}{4}$ inch in tenuity ; while the vertical jointing of the mass had the effect of breaking up these thin plates into sub-parallelopipedal forms. Towards the top of the well-shaft, a band of about 3 feet in thickness of very closely-cleaved rock was observed to be so much contorted as to be folded upon itself ;—evidently, as the result of some obstruction in the way, during the passage of the intrusive molten material.

It was noticed that the newly pegged-out roadway from Majiwána to Sisli and thence *viá* Wadála to Miáni, takes a parallel course with the abovenoted important dyke, and it may therefore be here suggested, that in order to convert the cleared ground into an economical traffic route, it should be provided with a raised resilient foundation, preferably drained, and then macadamised with a fairly generous layer of the naturally broken "metal," so abundantly strewed upon the surface and slopes of the adjoining dyke. It would, of course, be necessary to screen the dyke-shingle in order to secure "metal" of uniform gauge. When

examined, it was found that the pieces of detached shingle from the surface, of more than one inch across, were, for the most part, quite fresh and sound enough for ordinary road-making. Such material ought to yield a permanent level capable of withstanding fairly severe traffic, for at least two or more years ; and, if tarred and dressed with tarred granophyre chips, (to take the brunt of the wear and tear), its "life" would probably be trebled. At all events, although not so tough and strong as even weathered granophyre, the material for road-making purposes is unquestionably superior to any kind of calcareous stone and is so easily available in such prodigious quantities, that there can be no excuse why it should not be utilised more extensively.

From Sisli to Morwára the roadway takes a recurved course for 3¾ miles from NNW. to SSE. in the midst of a band of agricultural ground hemmed in by rock-plains;—the region being characteristically constituted by bedded lavas, more or less polyhedrally jointed. Some 2¼ miles SSE. of Sisli there is an appreciable relief, where, at old Sundráwadar the ground rises to form a hillock of 99 feet above the sea-level, which is continued ridge-like from WNW. to ESE. for a little more than a mile. The summit and slopes of this elevation are plentifully strewed with more or less decayed polyhedral shingle, and, when tested, the country-rock was found to be much tougher than that of the lower lying ground; so that here also a practically unfailing supply of utilisable road-metal may be sought for and found, to supplement the stock of dyke-shingle already alluded to, as a fairly good third-grade metal, adapted to the needs of well-constructed rural highways.

Approaching Morwára, the surface of the country-rock presents quite a variety of textures in bedded-lavas, which however, all agree in being more or less recticularly jointed. At places, the lava is closely amygdaloidal and zeolitiferous ; at others, it is liberally studded with small geodes of mixed chalcedony and quartz, or of mesolite and natrolite, which also traverse the rock in veins ; but, what is of more importance economically, the entire region appears to be criss-crossed by small and large dykes, some of which show signs of intense lateral compression by their closely cleaved character, while others are more normally developed, and capable of yielding practically unlimited supplies of angular shingle adapted for road-making operations, at small cost for labour.

Of the character just noted, is the long and prominent dyke which runs practically E. and W., about ¼ mile N. of Morwára, which can be traced almost continuously above-ground for a distance of more than

two miles, and which has been pierced at intervals by the well-shafts of local agriculturists.

Specimens of rocks and minerals registered since the last record, are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
12-12-15	195	Dense. Black Basalt Surface ..	Well-shaft, 500 yds. NW. of Majiwána.
14-12-15	196	Pale Buff-brown Miliolite-Limestone. Rubbly and Earthy.	Monsoon-flooded Plain, ½ mile S. of Sodhana.
14-12-15	197	River Wartu Sand	Bed of River. 1⅛ miles SSE. of Sodhana.
14-12-15	198	Tachylyte. Bed of River Wartu.	300 yards N. of Morána
14-12-15	199	Closely-jointed, Compact Lava ..	Of which 198 is a Selvage
14-12-15	200	Coarse to Medium Pale-buff Miliolite-Limestone.	Top of N. scarp of River Wartu. Immediately SE. of Bhomiawadar.
14-12-15	201	Blue-black, Basaltic Dyke-rock of the older series.	500 yards SSW of Simar. Dyke runs SSE. by SE. to NNW. by NW.
14-12-15	202	Closely Reticulated Bedded-lava.	Surface. ½ mile SW. of Rojhiwara.
14-12-15	203	Compact Bedded-lava, very slightly Amygdaloidal.	New well-shaft, from 15 ft. depth. 200 yards SSE. of Rojhiwra.
14-12-15	204	Dark-black Basalt Dyke runs, as low ridge, NNW. to SSE.	One mile SE. by SSE. of Adwána.
16-12-15	205	Bedded-lava, reticularly jointed and very slightly amygdaloidal; yields ½ to 2-inch polyhedra.	1¾ miles E by ENE of Adwána. Weathered out, from granular to small polyhedral shingle.
16-12-15	206	Reticulated Bedded-lava ..	From which 205 is derived.
16-12-15	207	Reticularly-jointed Bedded-lava. Very slightly amygdaloidal. Yields 1½ to 3-inch shingle.	Top of Ridge, ½ mile NW. by NNW. of Adwána.
16-12-15	208	Black Basalt. Dyke-rock ..	Well-shaft, 2 miles NW. by NNW. of Adwána.
16-12-15	209	Onyx. Geode and Vein-fragments.	2 miles NW. of Adwána.
16-12-15	210	Calcite. Narrow Vein	1¼ miles N. by NNW. of Bhatakri.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
18-12-15	211	Compact Bedded-lava. Pit Quarries. for local buildings	200 yds. SE. of Fatána Capable of large extension. Liable to water-log.
18-12-15	212	Compact. Slightly Amygdaloidal Bedded-lava.	100 yds. WNW. of Singra Temple. Bottom of 20 ft Well-shaft.
18-12-15	213	Cleaved Basalt of Dyke ..	500 yards E. of Sisli.
18-12-15	214	Siliceous Geodes, Onyx, etc. ..	¾ mile NNW. of Morwára
18-12-15	215	Cleaved Basalt. Weathered Dyke running NW and SE.	¾ mile NNW. of Morwára.
18-12-15	216	Compact Blue-black Basalt Dyke runs practically E. and W	¼ mile NNW. of Morwára.

Camp-Station X.—Morwara.

Enclosed Garden, 100 *yards ESE. of the Town.*

ARRANGEMENTS FOR WORK having been satisfactorily completed in camp by the evening of the 18th instant, the succeeding day was devoted to the trimming, registration and packing of specimens, and to the compilation of this report from the Diary and Field-book notes by the way.

At 8-45 a.m., on the 20th instant, an excursion was taken in a south-easterly direction to Bhárwára, and from thence northward past Khámbhodar to cover ground that had been left untraversed for this special occasion. At the very outset, a wide, but superficially ill-defined dyke of basalt was located to run from NW. by NNW. to SE. by SSE., only 100 yards E. by ESE. of the town.

The south-eastward roadway, after traversing nearly a mile of bedded-lava rock-plain, enters upon the alluvial fairly fresh-water land of the NE. moiety of the 'Ger' or Marsh, and the ground thereabouts is utilised, in season, for rice cultivation ; but, at present, is partially occupied by thriving cotton fields. The alluvial deposits vary very greatly in depth ;—ranging from less than one foot to over ten feet at sundry places, and notably at a spot where a stream-channel, traceable

to Bagwadar, cuts through the clayey soil to show a hardened sandy marl at the bottom, covered by earthly, richly fossiliferous alluvium, with slabs and small fragments of miliolite-drift imbedded in its uppermost parts. The fossils found are all of recent age, and principally belong to the genera *Potamides, Paludina, Planorbis* and a few stray valves of *Unio.*

Approaching Bhárwára, towards which the Ger alluvium encroaches, the surface of the ground grows gradually more and more miliolitic, until the roadway cutting through a bluff reveals the following geological structure ;—The bluff borders a broad valley filled with alluvium and lies 7 furlongs WNW. of Bhárwára. Its top is covered by about a foot in depth of coarse and fine slabs of false-bedded miliolite, overlying a thin layer of compact, rubbly miliolite conglomerate, which, in its turn is followed by about 4 feet of an earthy, incoherent, miliolite-conglomerate, with inclusions of limonitic limestone from the underlying Tertiary deposits, which are not here exposed, but may be seen *in situ*, exposed by the banks of the river $\frac{3}{4}$ mile farther south. The bed of the river at this part bears large quantities of fine sand, of which samples were taken for examination.

Bhárwára village stands on a foundation of coarse and frequently false-bedded miliolite, which diminishes to nil in the direction of Bagwadar and Khámbhodar ; where, however, the ground is rendered fairly calcareous by large quantities of miliolite drift.

It was formerly noticed, that a large proportion of the drift fragments around and about the town of Khámbhodar, consisted of thin flat slabs of a coarse texture and ruddy hue, so that it was not surprising to find that on the west side of the highway, about 3 furlongs SSW. of Khàmbhodar there is a narrow ridge-like hillock which runs SW. to NE. for about $\frac{1}{2}$ mile, composed of bedded-lava, thickly capped with the remains of a basement layer of coarse, sandy Dwárka Stone curiously deposited in thick laminæ of from less than $\frac{1}{2}$ to as much as 2 inches or more in thickness, just barely held together by interstitial ferruginous limy matter, so that the entire mass presents a singularly shaly aspect. The hillock top is literally riddled with pits, from which this insubstantial rubbish has been excavated for road-making.

From Khambhodar westward to Kindarkhera, the fertile countryside is well cultivated upon essentially pure regur soil derived directly from the decomposition of the bedded-lavas below. At Kindarkhera itself, the land is largely covered by alluvial soil ; while northward in the direction of Majiwána and westward, back to Morwára the bedded-

lavas of the Deccan-Trap Series constitute the entire surface of the country-side. No dykes of any size were discovered in this region; but a few of the low hog-backed hillocks and ridges were carefully examined, and found to exhibit exceedingly tough and strong material capable of being utilised as road-metal with decided advantage on the score of economy. Among these, special mention may be made of a manifestly crystalline olivine-dolerite, which forms a large quadrangular hillock $2\frac{3}{8}$ miles NE. of Morwára on the road leading to Majiwána.

Untraversed ground to the north of Morwara, was duly covered, on the 20th instant, by a journey of $4\frac{1}{2}$ miles from the camp to the north of Singra. During this excursion, the E. and W. dyke, already noticed, was re-crossed $\frac{1}{4}$ mile due N. of the town and found to exhibit normal angular shingle at the surface, at a place suitable for being excavated for the extraction of good road-metal material on a large scale. At this spot, moreover the bedded-lava or country-rock through which the dyke passes, is raised into a low, scarcely perceptible ridge which trends SW. to NE., and is composed of more than ordinarily tough material, polyhedrally jointed, and therefore capable of being also utilised as road-metal for country highways. The precaution must be taken however in excavating upon the elevations of this, and indeed upon all rock-plains composed of bedded-lavas, to discard patches of materia that are too closely amygdaloidal, if such material is destined for use as road-metal. Certain areas on the surface hereabouts, are so thickly studded with zeolitic amygdales, as to give the rock a singularly ornamental appearance; and, when quite fresh, such specimens, in even small dimensions, might be utilised by fancy-stone artificers, for the production of quaint clock-cases, ink-stands and the like. When weathered and sunbaked, the amygdales are very liable to crack asunder and drop out, leaving the hardened matrix of the rock in its original highly vesicular, almost spongy condition. It will therefore be gathered, that such textures, although capable, when perfectly fresh, of withstanding ordinary wet and dry attrition, would speedily succumb under severe crushing force, such as that occasioned by heavy and continuous cart-traffic; so that, as a rule, all, save only very slightly amygdaloidal lavas, should be unhesitatingly rejected, when tendered for road-making operations.

At a distance of $1\frac{1}{2}$ miles N. of Morwára, an E. and W. trending ridge of ground is encountered, which has lately been put under cultivation for the sake of the scanty soil which it affords. Excavations here, which would be naturally drained and free from fear of detrimental

water-logging, would yield an abundant supply of compact shingle, sufficiently tough for ordinary road-metal ; but, it will doubtless be called to mind, that the westward extension of this ridge rises to a summit of 99 feet above the sea-level, in form of a rounded hillock, $3\frac{1}{2}$ furlongs SE. of the abandoned village-site of Sundráwadar, the slopes of which are closely covered with 1 to 3 inch angular shingle in a tolerably fresh condition. Obviously, a slope-side quarry here would be sufficient to supply local wants, for road-making and repairing for many miles around with strict economy.

About one mile SSW. from the N. of Singra, the road from Morwára crosses the great E. and W. dyke to which frequent reference has been made, under the specific name of the Kunwádar-Majiwána-Sisli dyke. Good and abundant angular shingle capable of being screened to readily yield large supplies of fairly fresh, ready-made 'metal' of $1\frac{1}{2}$ inch gauge, could here be secured at a minimum of cost, for laying down upon the entire length of the newly marked roadway from Majiwána *viâ* Sisli and Wadála to Miáni ; and fresh quantities of perfectly sound, unweathered material can always be depended upon all along the length of the great dyke, (which averages 10 yards in width, down to a mean depth of 20 feet to the underground water-level), if wanted.

From the crossing of the great dyke by the cart-road from Morwára, for a distance of fully half-a-mile, a well-marked ridge of bedded-lava extends from S. to N. towards Singra, and being composed of more than ordinarily tough material, (*ergo* its persistence as an elevation), and reticularly-jointed on a moderate scale, offers a fresh variety of material, if required, for road-making purposes.

On reaching the north of Singra with its richly fertile gardens, observations were taken of the well-watered valley of the Kamad Nuddy, now fairly full of water, and it was found that the land to the north of Singra right up to the State boundary marked by the southern bank of the now comparatively narrow River Wartu, consists of an exceptionally deep layer of bedded-lava soil, with but only occasional exposures to indicate the nature of the rocks below. Thus, at the State boundary 2 miles NW. of Singra, both banks of the River Wartu show scarps of 15 feet of thoroughly decomposed bedded lava ; while similar soil continues more or less deeply developed all along the boundary area up to and beyond the cart-road leading from Sisli to Ráwál in Navánagar State. This road was followed up to Sisli, after crossing a shallow fordway, now dry, of the Kamad Nuddy, and the irregularly elevated long patch of ground to the immediate south of that watercourse was

found to show an exposure of reticularly-jointed, shingle-strewed bedded-lava, somewhat decayed.

On reaching Sisli, the Patel of the village earnestly requested the inspection of an old site, where a small dam, now demolished, had once held back the surplus drainage of the surface in form of a tank or reservoir. The site in question lies approximately ½ mile W. of Sisli, and is reached by following the course of the great dyke, (which intersects the village and continues westward past the State boundary nearly a mile farther on the road to Chandrawára in Navánagar territory), and then crossing south through a plantation of Babuls, (*Acacia arabica*), to where a streamlet carries the upland drainage towards a tributary from the Kamad Nuddy, a trifle over a mile to the north-west. It has, and doubtless correctly, been estimated that the reconstruction of a dam to constitute an irrigation "Talav" would amply justify any expense incurred, by securing a plentiful water-supply for fully 400 acres of excellent agricultural land, which is at present forced to lie fallow.

From Sisli south-westward on the road to Wadála, the ground for about ½ mile is covered with from 1 to 3 feet of alluvium due to overflows during successive monsoons of the neighbouring watercourses, but the bedded-lava soon outcrops as an undulating rock-plain for 1½ miles to the angle-boundary of the State, where an irregular rising area may be distinguished by the superior hardness of its rock, which exhibits numerous geodes and small veins of a siliceous character ;—chalcedony, quartz and zeolites.

Taking up the roadway from Chandrawára at this boundary, back to the camp at Morwára, nothing noteworthy remains to be recorded, beyond the observation that the land is constituted by a wide and almost treeless rock-plain with but a scanty supply of soil which is fully cultivated wherever a plough can be made to penetrate. The ground, moreover, notably in the NW. neighbourhood of Morwára is ultra-siliceous at many places, and frequently glistens and gleams in the sunlight from the numerous white fragments of geodes and veins of chalcedonic silica, quartz and species of zeolite. These, however, are of but little value in the crude condition; although they might be utilised by industrious villagers for fashioning into quaint curiosities, buttons, and so forth.

Tents were struck at Morwára at 9 a.m. on the 24th instant and the camp removed to Miáni, where, as sufficient accommodation was available in the Durbargadh buildings, work was conducted from those quarters

thereby saving the loss of practically one whole day. The journey from Morwára was taken *viâ* Wadála, and thence along the lower cart-road past the Naonara Talav to join the newly projected roadway near the sea-port town, and the following observations by the way, were duly recorded.

On leaving Morwára a visit was paid to the Patel's well cultivated fields and gardens on the north-western side of the town where the well-shafts were inspected and advice afforded on questions of water-supply and irrigation. While in this neighbourhood, the opportunity was taken to examine some of the well-shafts on the line of the E. and W. dyke which here cuts through the bedded-lavas $\frac{3}{4}$ mile W. by WNW. of Morwara.

One of the wells thus examined was being newly sunk a few yards out of the line of the dyke, and the anxious agriculturist wanted to know why he did not find any indications of a water-supply after having reached to a depth beyond the normal water-level. It was pointed out to him that he had sunk his shaft into previously drained bedded-lava, just outside of the water-holding dyke; but his labours were not entirely in vain, for it was found that he had unearthed the basal contact-zone of a lava-flow, which, in passing over the chilled surface of a previous bed of lava, must have had its steam-laden vesicles, propelled vertically upwards into the molten rock-mass, so as to form numerous straight or branched tubes of varying lengths,—seldom more than a few inches long. These stem-like vesicles when subsequently filled with secondary mineral matter, would, of course, be afterwards represented by the vertically disposed, more or less closely parallel rod-like amygdales found in the solidified lava;—the matrix of which, in the present instance, has also undergone profound changes, by being converted into a brick-red material, analogous with laterite. The specimens secured of this uncommon phenomenon in local bedded-lavas, present a singularly curious and even beautiful appearance of a deep brick-red ground traversed by sub-parallel rods of milk-white, (zeolitic), mineral matter coated with bright green glauconite. They are of scientific rather than of commercial interest.

About one mile west of Morwára, the long dyke abovenoted exhibits evidence of intense lateral compression, being revealed by a well-shaft there situated, from which large quantities of closely cleaved basalt, precisely similar to that observed E. of Sisli, have been extracted; but the vast bulk of the dyke-rock is of the nature of perfectly fresh deep-black basalt in polygonal pieces of from 6 to 8 inches or so in length

with a tendency to break with ease into a hard angular shingle suitable for road-metal.

While the bedded-lavas preserve their integrity as reticularly-jointed rocks, all the way from Morwára to Wadála there are a few instances to be met with of diversity in detail which are worthy of more than passing notice in this place. For instance, about 1½ miles WNW. of Morwara there is an eminence of irregular shape and of quite ½ mile across, which, by reason of its superior elevation, proclaims the power of being better able to resist subaerial denudation than its surroundings. When examined, the rock at first sight appears to be in no wise different from the lavas below, but upon careful scrutiny, especially of certain patches of weathered material, it is found to exhibit a very curious structure; being, in effect, jointed into small polyhedra, having an average diameter of a little more than an inch, with shrinkage spheroidal nuclei composed of very much harder material; so that when sufficiently decomposed, the small spheroids of approximately one inch in diameter, drop out entire, like so many schoolboy's marbles from the crumbling mass, when smartly tapped by a hammer.

Another feature, by the wayside on the road to Wadála, is that at about 1½ miles ESE. of the village, the road runs partially over an E. to W. trending dyke, traceable for about 5 furlongs aboveground; while only about 100 yards or so E. of the village, there is a jumbled mound composed of large blocks of black-rock, which might from a distance be expected to yield good building material; but which, upon examination was found to be amygdaloidal, tough and splintery; sub-reticularly jointed; and almost rhyolitoid, *i.e.*, showing flow-structure, accompanied by a fissility which renders the material quite unsuitable for either building purposes or road-metal. The amygdales, moreover, were found to be elongated and discoidal, pointing to a very rapid consolidation of the flowing molten magma.

Westward of Wadála on the route to Miani, the bedded-lavas of the Deccan-Trap Series continue to predominate for about a couple of miles, first of all as a partially cultivated country-side and then in form of a rock plain. Gradually, however, the surface becomes strewed with angular drift material of mixed miliolite and Tertiary fossiliferous limestones and consolidated sands, which probably belong to the Dwárka group of beds.

About 1½ miles E. of Miáni, on the N. side of the newly-marked roadway there is a well-shaft which throws some light on the geological structure of the ground. The section shows about 2 feet of soil, followed

below by 3 to 4 feet of compact conglomerate containing numerous fragments of Tertiary fossiliferous limestone and laterite, overlying 10 feet of a rubbly and earthy conglomerate.

Approaching Miáni, ½ mile ESE. of the town, the roadway runs past the termination of a Euphorbia-clad narrow ridge which trends from NW. to SE. in a sub-crescentic line, showing a cap of some three feet of coarse, freely honeycombed miliolite, resting directly upon a substratum of compact, consolidated shell-sand of Dwarka, or Post-Pliocene Age. From thence, the ground rises rapidly to the eminence, on the northern slopes of which the town is built, along the eastern scarp of the broad inlet known as the Meda Creek, and about one mile distant from its sand-spitted outlet into the open Arabian Sea.

Additions made to the collection of geological specimens may now be registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
20-12-15	217	Alluvium of Ger containing fresh-water shells of *Mollusca* of the genera *Potamides*, *Planorbis*, *Paludina* and *Unio*	1 mile SSW. by SW. of Kindarkhera. 5 to 10 ft. scarp. E bank of stream from confluence of drainage from Khámbhodar and Bagwadar.
20-12-15	218	Coarse to Fine Slabs of Compact Miliolite-base Stone.	7 furlongs WNW. of Bhárwára Top or Bluff. False-bedded.
20-12-15	219	Compact Rubbly Miliolite-Conglomerate.	Underlying 218.
20-12-15	220	Incoherent Miliolite-Conglomerate	Underlying 219.
20-12-15	221	Fine River-Sand, Large quantities.	3 furlongs SW. of Bhárwara
20-12-15	222	Fine to Coarse, Indurated and Shaly Dwárka Limestone.	Capping hillock of Bedded-lava, 3 furlongs SSW. of Khámbhodar.
20-12-15	223	Compact Bedded-lava	Hilly-mound, 2⅜ miles NE of Morwára.
20-12-15	224	Tough, Compact Bedded-lava. Reticularly jointed. Suitable for 'metal'.	1¾ miles NE. of Morwára, 150 yds. S. of road to Majiwána.
22-12-15	225	Sample of shingle from Dyke running practically E. and W. Suitable for Road-metal.	¼ mile N. by NNE. from centre of town of Morwara.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
22-12-15	226	Amygdaloidal Lava. Country-rock, reticularly jointed.	Surface of Rock-plain. 500 yds. N. of Morwara
22-12-15	227	Basic Bedded-lava Soil	1 mile N of Morwara
22-12-15	228	Sample of Angular Shingle Surface of Dyke.	7 furlongs SSW. of Singra. Abundant and suitable for 'metal.'
22-12-15	229	Decayed Subsoil from Edge of Dyke.	Dyke 228. Used for dressing new road, Majiwana to Miáni.
22-12-15	230	Polyhedral Shingle. Tough Bedded-lava, suitable for road-metal.	Ridge. ¼ mile S. of Singra. Abundantly strewed on slopes.
22-12-15	231	Amygdaloidal, siliceous and zeolitiferous Bedded-lava Shingle.	Hilly-ground. 1½ miles SW. of Sish at State-boundary.
24-12-15	232	Bedded-lava. Lowest Contact-zone Laterised and bearing Vertical Stem-like Amygdales.	From new well-shaft, ¾ mile W by WNW. of Morwára.
24-12-15	233	Amygdaloidal Bedded lava. Tough, splintery, in large blocks and sub-reticularly jointed.	Irregularly shaped Eminence. ½ mile across. 1½ miles WNW. of Morwara.
24-12-15	234	Minutely-Spheroidal Bedded-lava.	Sundry portions of 233.
24-12-15	235	Amygdaloidal Bedded-lava. In big blocks, with flattened or discoidal Amygdales due to consolidation during flow.	100 yds. E. of Wadála. The rock though tough, is splintery and fissile, and therefore of no commercial value.
24-12-15	236	Fossiliferous Conglomerate, with Tertiary Limestone and Laterite Inclusions.	1½ miles E. of Miáni.
24-12-15	237	Coarse, Sandy, Honeycombed Limestone.	Narrow Ridge-top, ½ mile ESE. of Miáni.
24-12-15	238	Consolidated Shell-Sand. (Dwarka).	Immediately underlying 237.

Camp-Station XI.—Miani.

The Durbargadh. SE. side of the Town.

AMPLE ACCOMMODATION for work being available within the Durbargadh inclosure of the town, the tents were, for the time being, stowed away ; and, early in the morning of Sunday, the 26th instant, a general reconnaissance of the country-side was made of the NE. quad-

rant to the boundaries of the State, and thereafter south-westwardly from Wadála to Tukra and back to Miáni along the inland roadway ;—leaving the $\frac{3}{4}$ mile-broad strip of coastal land to be investigated upon a future occasion.

At $2\frac{3}{4}$ miles NE. by ENE. from Miáni a sample of the Salt Marsh soil was taken, together with a number of semi-fossilised recent marine and freshwater shells of molluscs ; and it was noticed that certain patches at this part, laid bare by the winds, consisted of rubbly lumps and slabs of consolidated shell-sand precisely simliar to that being formed at present in favourable positions upon the beach of the open sea, and along the margins of the Meda Creek to the immediate east of Miáni.

After traversing the surface of the hardened alluvial mud of the marsh for some distance, a small bungalow was reached on the summit of a ridge of slightly amygdaloidal bedded lava, called Nagarari Dhár, $3\frac{3}{4}$ miles NE. of Miáni. This ridge of hog-backed hillocks runs practically eastward to the boundary of the State for $\frac{3}{4}$ mile, and being composed of medium-meshed reticularly-jointed lava, continuously sheds an abundance of tough angular shingle, which could economically be gathered and dumped down on to the newly-marked roadway which skirts the boundary line and continues for $1\frac{1}{8}$ miles SSE. to Wadála. The new roadway from the N. of Nagarari Dhár, covers an almost perfectly flat rock-plain of the bedded-lava all the way along the boundary, until, upon approaching Wadála its surface is temporarily obscured by from 1 to 2 feet deposits of alluvium from the marsh.

From Wadála the SSW. by SW. cart-road was followed *en route* for Tukra and the following noteworthy occurrences were duly recorded by the way. At a distance of about one mile from Wadála the ground by the side of a small stream was noticed to show signs of laterite ; but, upon examination it was found to exhibit only a small accumulation of re-consolidated, coarse laterite-conglomerate, with indications of Tertiary and miliolite fragmentary inclusions.

One mile farther along, or approximately 2 miles SSW. of Wadála, a small red hill was encountered, from which samples were taken to show its structural peculiarities. The summit of the hillock was found to show slabs of a fossiliferous Tertiary limestone heavily stained to a deep brick-red colour, and associated with blocks of an evidently foraminiferal limestone, likewise indued with lateritic stains to a deep purple-red hue. Underlying these, the rock consists of a very coarse brecciated laterite conglomerate, which, by metasomatism· exhibited patches and

segregation veins of a chalky-white material in subordinate quantities, of which samples were secured for laboratory examination.

This lateritic formation was traced to extend in ridge-like hillocks for $\frac{3}{8}$ mile in a NW. direction and $1\frac{1}{8}$ miles to the SE.; while, from the latter portion, it spreads widely SW. for $1\frac{1}{4}$ miles right up to the village of Tukra. The whole of the country-side for a considerable distance around and about this ridge is 'literally painted red' with the débris from these heights, although the laterite proper is nowhere prominently exposed. There can be no room for doubt, however, that the true lateritic cap to the original hog-backed hillocks of bedded-lava, lies low beneath the visible lateritic-conglomerate; which, from its fossil contents, must be assigned, in its origin, to the Tertiary,—probably Pliocene,—Age.

Evidence in support of the abovenoted conclusion is not wanting; for upon proceeding barely $\frac{3}{4}$ mile farther, or $5\frac{1}{2}$ furlongs NNE. by NE. from Tukra, a small hillock, forming part of another (non-lateritic) ridge, reveals a characteristic series of beds of Miocene and Post-Miocene (Dwárka) Age. The summit of the hillock is capped by thick slabs of a pale, ruddy-buff calciferous sandstone or arenaceous limestone, azoic above, but distinctly fossiliferous and conglomeratic below. Underlying this there is a zone of richly fossiliferous conglomerate, loosely textured, earthy, and crowded with the fossilised shells of marine, Gáj, *Mollusca*. This bed lies conformably upon a substratum of very yellow, broken blocks of limonitic limestone of the Pindáralite type, which in its turn appears to be deposited upon the bedded-lavas of the Deccan-trap.

On approaching Tukra, almost within a stone's-throw of the village, the hilly and undulating ground grows red with a widespread deposit of a compact, but somewhat coarse-textured laterite-conglomerate, composed of laterite pebbles cemented together by limonitic decomposition products, the true nature of which remains to be revealed by determinations under the microscope. This stone furnishes a distinct variety of laterite-conglomerate, which future blasting operations might probably reveal in commercially workable quantities as a new kind of ornamental stone, and has therefore been registered under the name of "*Tukralite.*"

From Tukra, the upper roadway to Miáni, which runs north-westwardly at a mean distance of $\frac{3}{4}$ mile from the sea-shore, was followed, over ground covered for the most part with blown sand. The underlying rock, fitfully exposed, was, for the most part, found to consist of a sandy, indurated, limestone of probably Dwárka Age, with occasional thin patches of miliolite limestone.

Midway, between Tukra and Miáni, on approaching the village of Bhavpura, the erosion of a nala by the roadside, revealed the presence of a fairly thick bed of compact, but much decayed stone having all the outward appearances of a hard consolidated shell-sand ; but, when chipped, was discovered to disclose a vertically-disposed tubular structure, strongly reminiscent of organic structure. Should this, upon microscopical examination, turn out to be part of an astræan corallum, it would go far to prove the existence of a fringing coral-reef in closing Tertiary times.

At Bhavpura, a well-shaft was inspected and found to show a superficial layer of whitish, but somewhat fissile, indurated, consolidated shell-sand, of but small commercial value, to the total thickness of five feet, resting, apparently without any intervening conglomerate upon several feet of thoroughly decomposed bedded-lava, in which rows of spheroidal nuclei could be detected. These nuclei when broken open were found to be completely altered into a soft, bluish-green earth.

On the 29th instant, it was decided to investigate the coastal exposures around and about Miáni and all along the shore line as far as the village of Tukra. For this purpose it was found necessary to enlist the services of three men to carry tools and samples, and to make the traverse on foot.

Proceeding for about 300 yards SE. by SSE. from the back of the Durbargadh, to the top of the hillock there situated, it was found, that, resting upon a thick substratum of consolidated shell-sand of Dwárka Age, the hillock, extensively quarried to a maximum depth of 20 feet, consists of beds of compact, coarse and sandy limestone of a brown-buff colour and inferior quality. Passing the Bandar and then northward along the strip of sandy shore at the base of the E. scarp of the Creek, the low cliff-like scarp was climbed to reach the site of the Level Datum Pillar of the Trigonometrical Survey, which is situated approximately $\frac{1}{4}$ mile NNW. of the Durbargadh Gate.

The deep deposit of miliolite quarried on the SE. hillock, was found to thin down rapidly in the direction of the Level Datum Pillar, which is erected upon beds of coarse, sandy and much honeycombed miliolite, varying from 3 to 6 feet in thickness and resting directly, without any intermediate conglomerate, upon a deep deposit of Tertiary (Dwárka) consolidated shell-sand. The miliolite lies like a low terrace upon the compact shell-sand which shelves down for about 100 yards westward to form a steep scarp or cliflet bordering the east bank of the Meda Creek.

Upon closer examination, the deposit of shell-sand, is found to vary from 10 to 14 feet in thickness ; and, although much decayed and crumbly at the surface, is constituted by a compact, indurated material of a greyish white texture, which could be utilised, if in any other situation for building-blocks of an enduring character. The edge of the cliflet, running parallel with the creek shore moreover, was found, for the width of a few yards to be composed of a finely fibrous material, vertically disposed, and presumably of organic origin, probably of the nature of a dead coral reef, similar in structure to the stone already noted as occurring on the surface in the neighbourhood of the small village of Bhávpura.

The strip of shore at the base of the cliflet, is covered in patches with fine sand, plentifully strewed with dead marine shells, principally of the genera *Ostrea, Cerithium, Cardium, Tellina* and a few other estuarine and marine forms of life ; while the exposed floor, (beneath the sandy patches), and immediately underlying the scarped consolidated shell-sand, and manifestly forming its basal layers, is composed of false-bedded slabs of hardened shell-sand, full of inclusions of Gáj limonitic limestone, laterite pebbles and a few well-rolled fragments of basic volcanic lava. There can thus be little doubt that the consolidated shell-sand, probably belonging to the Dwárka Group of beds, here lies directly upon Miocene strata, which in their turn were deposited upon the laterite and bedded-lavas of the Deccan-trap. The cliflets reach their maximum height about a furlong or so north of the Level Datum Pillar, to thereafter diminish and fall back inland to the north-east, where they finally vanish beneath the alluvium of the marsh.

Travelling in the opposite direction seaward, to the south of Miáni, it was found that the deeply quarried deposits of coarse miliolite already noted, are denuded down towards the sea-shore, where they are over-lapped by blown-sand, and a small proportion of alluvial drift to give birth to a small bight hemmed in by a narrow spit of sand where a few stunted mangroves struggle for a bare existence and numerous sea-fowl,—pelicans, flamingoes and others haunt the silting harbour. On the sheltered stretch bordering the bight, the fierce rays of the sun have baked the rough, corrugated, bared surface of the miliolite to a brick-red colour for the depth of an inch or so ; but a few hundred yards inland, or about 1½ miles SSE. of the Level Datum Pillar, the thickly sand-covered miliolite rises to the height of 39 feet above the sea-level and, from a well-shaft, sunk in the neighbourhood, shows thick, cancellated, obliquely-laminated, beds of coarse, sandy miliolite to a depth

of more than 25 feet. This deposit of miliolite was found to slope down shorewards and to tail down irregularly inland in a SE. direction, more or less deeply covered with blown sand right up to and beyond the '*Pahlia*' to the south of Tukra ;—a distance of fully 3½ miles of dunes of fine utilisable sand, samples of which were secured for laboratory examination.

From Tukra, a drive ENE., was taken as far as the ruins of Hathiáni Derá,—a distance of 3¼ miles, and the following geological observations were recorded :—It was found that the laterite-conglomerate which encroaches upon the northern moiety of the village, disseminates a drift of fine fragments, mostly of earthy hæmatitic ore, over the entire countryside, which, however, stops short of a small stream ½ mile ENE. of Tukra, where the shallow erosion shows an overlapping of much-broken pale-yellow, fossiliferous, Miocene limestone.

Proceeding ENE., the ground rises to an undulating elevation, which is capped by a thin bed of compact dark-yellow limestone of the Pindáralite type, but too much broken and shattered to be of any commercial consequence. This occurs about ¾ mile ENE. of Tukra, after which the surface deposits continue to present an essentially Miocene facies, for fully 2½ miles ENE. of Tukra, diversified at sundry places, by patches of rubbly, compact miliolite-conglomerate, full of fragments and pebbles of both Gaj limonitic-limestone and laterite, of all of which samples were taken for the State Geological Collection.

The Miocene deposits continue to predominate right up to and beyond the Hathiáni Temple ; but, at about ¾ mile WSW. of the ruins, a very low and narrow ridge, about 200 yards wide and ¾ mile in length protrudes, like an outlier of laterite, trending from W. to E., through the overlapping limonitic limestone.

It is just in such situations that one would expect the subsoil to become altered into greyish clayey deposits differentiated here and there by more or less limonitic layers, commonly known as the yellow-ochre of commerce ; and it was not therefore surprising to find a small exposure of very pale yellow-ochre on the SE. scarp of the Hathiáni Vokala, ¼ mile ESE. of the small village of Sakhpur.

From Sakhpur and the adjoining ruins of Hathiáni Derá, the NW. by NNW. cart-track was followed, first, for a furlong or two over Gáj, limonitic-limestone ground, and then upon an uninterrupted plain of bedded-lava, up to Wadála, where, ½ mile SE. of the last-named place, the E. and W. bearings of a 30 feet wide dyke, pierced by a newly-dug well shaft were duly recorded for mapping.

So many rumours were current about the occurrence of valuable deposits of gypsum in the neighbourhood of Miáni, that a special search for the mineral, which had not hitherto been met with, was planned and carried out on the 30th instant.

A drive was taken NE. by ENE. for a distance of $2\frac{1}{2}$ miles from Miáni to the borders of the Salt Marsh, and thence over the drying, alluvial mud in the direction of Nagarari Dhár, where a halt was called, some $\frac{7}{8}$ mile S. by SSE. of the Bungalow on the last named hillock. Here '*khodalis*' were called into operation, and it was found, that for a depth of from a few inches down to a maximum of two feet, the alluvial deposits yielded a fairly plentiful supply of 'fingers' of incipient selenite, imbedded sub-vertically and more or less incorporated with mud.

It appears that these deposits of gypsum, were discovered accidentally while constructing a channel through the alluvium to divert the freshwater surface drainage (derived from the NE. uplands), from the incoming salt-water of the Meda Creek and estuary of the Wartu-delta on the W. and SW. This periodic mingling of the silt-bearing freshwater with the brine, and their subsequent evaporation season by season would very naturally cause a deposition of hydrous sulphate of lime with clinging impurities into the sediment ; for it is well-known that the gypsum contained in sea-water begins to be precipitated as soon as 37 per cent. of water is lost by evaporation, but that if the water becomes diluted before the point of saturation of common salt is reached, namely, when and after 93 per cent. of the water has been driven off ; or, if the salt (sodium chloride) is dissolved away by the subsequent addition of fresh water,—the gypsum alone will be found to accumulate in the deposit.

From the circumstances noted above it will be gathered that some such reaction takes place periodically over that area of the salt marsh, the central part of which has been indicated ; but the gypsum, on account of its rapid accumulation and admixture with silt, is but of poor quality-although selenitic in variety, and doubtless well worth while being gathered for agricultural purposes.

Returning to the margins of the marsh on its southern borders where the ground is not entirely obscured by alluvium, the base of the salt-marsh is revealed at places to consist of a pale-yellow fossiliferous limestone, of probably Dwárka-beds age, upon which there are evidences of a littoral formation and raised beoch bearing densely-crowded aggregates of fossil (Pleistocene) oyster-shells, underlying a thin denuded remnant of slabs of almost azoic arenaceous limestone ;—the whole doubt-

less representing the final phases of the Dwárka group of beds of Newer Pliocene or Early Pleistocene Age.

The specimens collected and registered on the geological list are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
26-12-15.	239	Salt-marsh Soil, Blown Dust ..	$2\frac{3}{4}$ miles NE. by ENE of Miáni.
26-12-15.	240	Sub-recent Fossil Shells	Same locality as 239
26-12-15.	241	Consolidated Shell-Sand	Underlying 239.
26-12-15.	242	Bedded-lava. Tough, irregularly jointed shingle. Slightly amygdaloidal	Nagarari Dhár. Low, hog-backed ridge. $3\frac{1}{4}$ miles NE. of Miáni.
26-12-15.	243	Laterite-Conglomerate. Coarse and ill-defined.	1 mile SSW. by SW. of Wadála. Small road-side and field exposures
26-12-15.	244	Altered Bedded-lava Pale dove-coloured by exposure, etc	A few yards beyond 243, eroded by small nala
26-12-15.	245	White. Decomposition Segregation in fissure of Laterite-conglomerate.	2 miles SSW of Wadála, on road to Tukra.
26-12-15.	246	Coarse Laterite-conglomerate ..	Same locality as 245
26-12-15.	247	Laterised. Coarse. Fossiliferous Conglomerate.	Overlying 246.
26-12-15.	248	Laterised. Fine. Fossiliferous Conglomerate.	Overlying 247.
26-12-15.	249	Calciferous, Sandy Stone. ..	Summit slabs capping hillocks. $5\frac{1}{2}$ furlongs NNE by NE. of Tukra.
26-12-15.	250	Basement-beds of 249. Fossiliferous.	Immediately underlying 249, slightly conglomeratic.
26-12-15.	251	Fossiliferous Conglomerate and Fossils.	Immediately underlying 250.
26-12-15.	252	Limonitic (Gá) Limestone ..	Immediately underlying 251.
26-12-15.	253	'Tukralite' or Laterite-Conglomerate with Gáj Matrix.	200 yards NE. of Tukra, covering a large area.
26-12-15.	254	Coralliferous Limestone. Evidently remnants of a Reef.	$1\frac{3}{4}$ miles NW. of Tukra, just to S. of Bhávpura.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
26-12-15.	255	Consolidated Shell-Sand	Surface Stone of Bhávpura.
26-12-15.	256	Highly-altered Spheroidal Nuclei of Bedded-lava.	10 ft. from surface in well-shaft 25 yards SW. of Bhávpura.
29-12-15.	257	Coarse, Sandy Miliolite, 20 ft. ..	300 yards SE. by SSE of Miáni.
29-12-15.	258	Fine Buff-brown Miliolite 3 to 6 ft. Much honeycombed.	Denuded base on surface of which Level Datum Pillar, Miáni, stands.
29-12-15.	259	Consolidated Shell-Sand	Immediately underlying 258.
29-12-15.	260	Coralliferous Limestone. Probably Fringing-reef of 259.	Edge of 10 ft. Creek-scarp, also immediately below 258.
29-12-15.	261	Coarsely-textured, Fossiliferous Shell-Sand. Conglomeratic.	Immediately underlying 259 and 260 at base of Creek-scarp.
29-12-15.	262	Loose Shell-Sand of beach ..	Base of Creek-scarp, Miáni.
29-12-15.	263	Honeycombed Miliolite, superficially sun-baked to red.	1¼ miles S. by SSE. of Miáni, 200 yards E. of Old Mandir.
29-12-15.	264	Fine, Blown-sand, top of slope of Dune.	1½ miles SSE. of Miáni and ¼ mile SE. of Old Mandir.
29-12-15.	265	Rubbly, Gáj-Limestone from Loose, Earthy Conglomerate.	½ mile ENE. of Tukra, 1 ft. scarp of small nala.
29-12-15.	266	Compact but Broken. Gáj. Limonitic-Limestone.	¾ mile ENE. of Tukra, low ridge Pindáralite-type.
29-12-15.	267	Limonitic-Limestone Soil. Conglomeratic and fossiliferous.	Ploughed field, underlying 266.
29-12-15.	268	Rubbly Miliolite-base Conglomerate. In patches.	Superficial. 1 mile ENE. of Tukra.
29-12-15.	269	Red, Lateritic-Soil	½ mile WSW. of Hathiáni Derá.
29-12-15.	270	Pale Yellow-Ochre, only locally used by villagers.	¼ mile ESE. of Sakhpur, on SE. scarp of Hathiáni Vokala.
29-12-15.	271	Black-basalt of 30 ft. Dyke ..	Runs E. & W., ½ mile SE. of Wadála.
30-12-15.	272	Gypsum, sub-vertically deposited in top 6 to 8 ins. of Alluvium.	⅞ mile S. by SSE. of Bungalow. Nagarari Dhár In Salt-marsh.
30-12-15.	273	Gypseous Mud of Marsh	Same site as 272.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
30-12-15.	274	Fossil Shells. Oyster-bed of Raised-beach.	$2\frac{1}{2}$ miles WNW. of Wadála, on border of Salt-marsh.
30-12-15.	275	Arenaceous, slightly fossiliferous, Pale-buff Limestone.	4 to 6 in. slabs, surface of 2 ft. scarp of Marsh Overlying 274.
30-12-15.	276	Arenaceous, Fossiliferous Limestone.	Underlying 274.

DIGEST OF DIARY.

January, 1916.

ON NEW YEAR'S DAY the camp was transferred from Miáni to Visáwára, and tents were pitched under the shade of a spreading Banyan Tree, (*Ficus bengalensis*), near by the historic 'Mul Dwárka Derá' or old Dwárka Temple, about 500 yards or so NE. of the town.

To cover ground hitherto untraversed, a south-eastward course was taken for $1\frac{3}{4}$ miles, along the inland sub-coastal roadway skirting the eastern flank of the long, low, narrow, euphorbia-clad ridge, which, it will be remembered, was formerly, (on the 24th December, 1915), observed to be constituted by a thin deposit of coarse, sandy, honeycombed limestone, overlying the compact, consolidated shell-sand of the Dwárka Group of Beds. This narrow ridge was traced to rise from about 3 furlongs ESE. of Miáni, and to take a SE. crescentic bend for $1\frac{5}{8}$ miles, to vanish thereafter under accumulations of blown-sand, at a mean distance of about one mile from the open sea-shore.

On reaching the ruins of the ancient temple—Pánch Derá,—$1\frac{1}{2}$ miles SE. from Miáni-Durbargadh,—which is said to have once been included within the town-limits of the port, in the heyday of its prosperity,—a well-shaft, adjoining the temple, was inspected and found to show, according to the testimony of the local farmer, a perennial supply of potable water ten feet deep, at a depth of only 15 feet from the surface. As far as could be made out, the geological structure of the ground showed a surface deposit of coarse, false-bedded miliolite, overlying a few feet in thickness of Dwárka shelly-limestone, resting directly upon decayed

bedded-lava, through which a narrow dyke of basalt appears to have been intruded from WSW. to ENE.

From Pánch Derá, a cut across the open, cultivated countryside was taken, mainly over bedded-lava soil mixed with calcareous débris from the neighbouring miliolite and Tertiary limestone deposits, in a south-eastward direction to a spot approximately one mile N. by NNW. of the village of Tukra. This traverse was instrumental in determining the boundaries of the lateritic outcrops to the NW. of the last named village, which were found to extend in ridge-like continuity, from a part 1½ miles NNE. of Tukra, for nearly ½ mile in a NW. direction ; while the drift material from these low hog-backed elevations was spread so far and wide, as to convey the illusion of a much larger lateritic area than that which actually exists. The lateritic outcrops in this particular region, moreover, are not in reality constituted by the substance *laterite*, as such ; that is to say of rock, *in situ*, that has been altered by metachemic re-actions, principally through the agency of monsoon conditions ; but of sedimentary stone of the nature of laterite conglomerates, frequently bearing organic remains, or entirely composed of miliolite or earlier limestones that have become so highly charged with infiltrated laterite-products as to have undergone a kind of pseudomorphosis into a material closely resembling true laterite to the naked eye. Under the micros-cope, the precise nature and origin of these rocks, can, of course, be instantly demonstrated.

At rather less than one mile N. by NNW. of Tukra, the solid rock of the bedded-lavas of the Deccan-Trap Series, is prominently exposed at the surface to form the banks and bed of a deep stream running from E. to W., and cut by a rough cart-track leading SSE. to Tukra. The ex-posed bedded-lava at this site is of the nature of a closely amygdaloidal basalt, sunbaked to a deep brick-red colour superficially ; but does not appear to be present in sufficient quantity to claim attention as a profit-ably workable ornamental stone.

Taking the cart-track southward, across the abovementioned stream, towards the west of Tukra, another lateritic ridge is encountered about ½ mile NNW. of Tukra which is clearly in continuity with the rock registered as No. 253, under the new name of *Tukralite*, which forms the surface of the rising grounds 200 yards NE. of the village ; but, while the latter appears to be a medium-textured laterite-conglomerate with its deep-red pebbles cemented together by a yellow limonitic matrix, the bulk of the material, in the present instance, may appropriately be named a *Pisolitic-laterite* ; inasmuch as it is constituted by a composite

mass of pea-sized pellets of laterite, the precise nature of which can only be determined by microscopic examination of prepared thin sections of the substance ; but which may nevertheless be shrewdly guessed to be either of organic or concretionary origin, due to pseudomorphosis.

Whatever the origin or nature of these rocks may be, there is every reason to expect, that when properly prospected by either core-drilling or blasting, a sufficient quantity of sound material in blocks of suitable dimensions would be available, and speedily find favour as ornamental stones of unique appearance, capable of being easily tooled to yield a novel variety of quaint wares, such as fancy vases, clock-cases, occasional table-tops and so forth.

From Tukra, the south-eastern cart-road, running practically parallel with the sea-coast about one mile inland, was taken to the town of Visáwára, mainly over soil derived directly from limestones of the Dwárka Series of Beds of probably Pliocene Age ; but, about $1\frac{1}{8}$ miles NW. of Visáwára the underlying strata of Miocene Age commenced to appear at the surface ; and samples of a soft, pale-yellow, richly fossiliferous or Gáj limonitic-limestone were secured from a well-shaft there being sunk.

The specimens added to the State Geological Collection, were duly registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
1-1-16.	277	Closely Amygdaloidal Lava. Sunbaked to Brick-red Colour.	$\frac{7}{8}$ mile NNW. of Tukra on N. side of Stream-ford.
1-1-16.	278	Pisolitic Laterite	Ridge-hillock, $\frac{1}{2}$ mile NNW. of Tukra.
1-1-16.	279	Soft, Light-yellow, Fossiliferous Gáj Limestone.	$1\frac{1}{8}$ miles NW. of Visáwára. New well-shaft.
1-1-16.	280	Gáj Fossils. *Mollusca*	Same site as 279.

Camp-Station XII.—Visawara.

Adjoining Mul Dwárka Derá, NE. of the Town.

AS ALREADY RECORDED, the camp was duly installed at Visáwára on New Year's Day, and the monthly accounts of the Department having been prepared, were conveyed on the following day by the

Clerk to the Hazur Office at Porbandar. The Clerk returned to Camp on the 5th instant with bad news ; to the effect, that one of the wheels of the gharry was smashed to pieces by an accident due to exceptionally rough roads on the return journey, and that the vehicle had to be conveyed on a cart, back to Porbandar for repairs.

In the interim, active work was carried on in the camp, by overhauling the collection of specimens, trimming and securing chips for microscopical examination, and packing them securely for conveyance to headquarters ; and, as the gharry did not return duly repaired until the evening of the 10th instant, it was resolved to carry on the work of surveying on foot, accompanied by a bullock-cart to carry the specimens collected.

Accordingly, on the morning of the 7th instant, a bullock-cart was hired for the day's work ; and, with the help of three coolies, a traverse was made of the environs of Visáwára, as follows :—

A brief halt was called on the N. outskirts of the town where a high crescentic earth-dam serves to collect the surface drainage during the monsoon, to form a tolerably large reservoir or *talav*, which was found to still hold a sufficient quantity of water to attract numerous flocks of wild-ducks. The main drainage of the northern uplands, flows into this talav from the NE. by way of a small stream, the channel of which already shows an accumulation of from 1 to 3 feet of alluvium obscuring beds of fossiliferous Gaj, (Miocene), limonitic-limestone, continuous with the deposits already noticed at the surface $1\frac{1}{8}$ miles NW. of Visawara.

Immediately to the south of the talav dam, and practically forming the foundations of the town, the Tertiary deposits were found to be overlaid by an appreciable thickness of coarse, sandy, ruddy limestone, of but small commercial value, on account of its variable, much broken and slab-like character. The stone, however, has been largely utilised locally for cottages and walls, and was found to thicken considerably towards the SW., S. and SE. of the town, where several well-shafts revealed beds of solid but much honeycombed rock to a depth of about 10 feet.

About 300 yards S. by SSE. of Visáwára the limestone is superficially and sometimes deeply exhibited to form a wide rock-plain supporting sturdy clumps of *Euphorbia nereifolia*, and large slabs of the stone have here also been desultorily extracted for local use.

Continuing southward for about $2\frac{1}{2}$ furlongs from Visáwára, the channel of a stream, running ESE. to WNW. to the head of Visáwára Creek, $\frac{1}{2}$ mile SW. of the town, was examined and found to have left a marginal deposit or low terrace of consolidated river-gravel. Before

bending to join the Creek, however, the channel of the stream is always more or less filled with tidal water, and its re-entering angle and opposite bank show good exposures of false-bedded, very compact slabs of shelly-limestone, clearly belonging to the Dwárka Group of deposits, which bear marks of having been quarried on a small scale. These beds lie exposed, practically parallel with the sea-shore, at a distance of about $\frac{1}{2}$ mile inland, in form of a low ridge which extends from $\frac{1}{2}$ mile SW. of Visáwára, and runs uninterruptedly for $1\frac{3}{4}$ miles SE. along the NE. bank of the Creek. It is just possible that this stone might at some future date be turned to profitable account, since it is sufficiently compact and indurated to take a good polish and although seldom available in slabs of more than 4 or 5 inches in thickness, might nevertheless be used for minor ornamental purposes and for mantelpieces and table-tops under the designation of a "Shell-sand Marble."

Evidence of the existence of a gigantic fringing reef of mainly astræan corals towards the close of the Tertiary or commencement of the Quaternary Era, forming a huge coral-zone belonging to the Dwárka Group of beds, is to be found in fine exposure towards the mouth of Visáwára Creek, at the surface of the W. scarp, where the denuded dead coral-rock, from 1 to $1\frac{1}{2}$ feet in thickness may be seen standing, *in situ*, upon a base of from 2 to 3 feet of rubbly calcareous conglomerate. This rubbly stratum passes below into beds of apparently azoic, arenaceous, compact slabs of limestone which form the bed of the creek.

The coral-reef at this part, with its associated underlying beds, all manifestly belonging to the Dwárka Group, can be traced for a distance of over 500 yards seaward; where the structure, facing the open sea, is capped for about a couple of hundred yards or so by other deposits. These latter were found to consist from below upwards of from 2 to 3 feet of loosely-textured gravelly-rock, merging above into a rubbly and then compact, cancellated, light ruddy-brown limestone, some 10 feet in thickness; contributing with the subjacent coralliferous structures to form a sea-scarp of about 20 feet, covered by a thin layer of blown-sand. At the base of this scarp a wide stretch of fine-sand constitutes the sloping seaward beach. Samples of this sand of which vast quantities, in uniform quality, are available, were taken for laboratory examination.

Turning inland in a NNW. direction for $\frac{3}{4}$ mile, and about $\frac{1}{2}$ mile W. of Visáwára, a couple of well-shafts were examined and found to reveal the continuation underground of the coral-reef, already noted as fringing the coast-line; but the corals themselves had undergone considerable

calcification by reason of the infiltration and deposition of secondary calcite. The coral-rock, although sometimes employed for building purposes by villagers, cannot very well be classed,—as it is in southernmost India,—as a building-stone ; but it might nevertheless be utilised for burning into lime of a superior quality, such as is commonly used by natives for their *pán-supári*.

On the 10th instant, a second excursion was made on foot, with a bullock-cart and two coolies, to explore the coastal region constituted by the tongue of land lying between the sea-shore and the south-western bank of Visáwára Creek, and stretching south-eastward to the northern confines of the village of Rátari.

At about 500 yards E. of Visáwára, a well-shaft was examined and found to show a water-level at the depth of 21 feet ; the entire shaft being sunk through a highly ferruginous, rubbly and concretionary conglomerate which evidently forms the base of the deposit of denuded rock upon which the town is built, and which doubtless rests upon strata of Tertiary Age.

Proceeding over formerly traversed ground towards the mouth of Visáwára Creek, the creek itself was crossed over by way of a ford,—now almost dry,—locally called ' Buldh Bárá ', 6½ furlongs S. by SSE of Visáwára. It was here observed that the succession of strata noted as occurring at the mouth of the creek are practically repeated on a slightly modified scale. The coral-reef rock was found to be attenuated and covered by a thin layer of gravelly stone at one part where the creek-scarp measured but a couple of feet deep ; while scarcely 500 yards farther NW., the 10 feet of creek-scarp showed a replacement of the coral-reef rock by a thick deposit of false-bedded slabs of compact shelly and sandy limestone surmounted by from 3 to 5 feet of beds of loosely-textured consolidated gravelly stone ; which, together with the former, had been sparingly quarried for the erection of village dwellings, well-shaft linings and walls.

Cutting across the abovenoted formations for ¾ mile in a south-eastward direction to the sea-shore, about 1½ miles S. by SSE. of Visawára, a favourable exposure was described which exhibited the miliolite as a compact solid mass, of much honeycombed, coarse and sandy limestone in form of a vertical sea-scarp from 6 to 7 feet high, resting directly upon beds of a very compact conglomerate largely composed of coral-rock and hard, shelly-limestone ; the latter being left bare for about ten yards, and then cut sharply down to form a second sea-scarp of 4 feet nocked at its base by the sandy beach, covered by high-tide.

Large quantities of fine sea-sand are found to cover the lower terrace of the raised-beach now in the course of formation ; while the upper terrace, or surface of the miliolite, furnishes a temporary resting place for accumulations of coarse shell-sand. Farther inland, all the rocks are obscured by blown sand held together nearest to the shore, in the form of long, narrow, broken ridges by the strong network of rhizomes or underground creeping-stems of the beautiful purple-bloomed *Ipomœa biloba ;* and a little farther inland, by hummocky dunes, resembling at a distance the so-called glacial *roches moutonnées,* or the rounded backs of a vast flock of sheep, caused by the growth of clumps of *Heliotropium ovalifolium, H. indicum* and sundry sedges ;—notably *Carex indica* and *Cyperus rotundus,* all of which serve in no small measure to prevent the sand from drifting inland to ruin the adjoining agricultural areas.

South-eastward of the geological section just described, right up to Ratari and beyond, the sand dunes obscure everything and slope gently down to vanish beneath the level of the sea ; and there can be no doubt that if excavated, the deeper layers of these dunes would be found consolidating, if not already consolidated into more or less compact, utilisable stone. This indeed is frequently foreshadowed by the partially consolidated exposures revealed by many of the deeper canõn-like runnel-channels that serve to drain the dunes during the rainy-season.

Samples collected on the previous day were duly trimmed, registered and packed as usual, on the 11th instant ; and the welcome gharry having returned, properly repaired, a new traverse, under more favourable conditions, was made on the following day to investigate the structure of the countryside to the N., NE. and E. of Visáwára.

Following the N. by NNE. cart-road from Visáwára over ground sparingly encrusted with miliolite resting upon an equally slight substratum of Dwárka-beds shelly limestone, the remains of a ruined Temple were found at a distance of ½ mile from the town, built upon an outcrop of laterite, forming a small elevation of about 100 yards in diameter. At this place the surface of the ground commenced to reveal the presence of the underlying Miocene beds by an outcrop, overlapping the laterite, of Gáj limonitic-limestone of the Pindaralite type, but much shattered and so poorly developed as to be commercially worthless. Half-a-mile farther on, in the same direction, slabs of false-bedded Dwárka shelly-limestone were observed on the roadway to lie conformably upon the characteristically yellow Gaj limestone ;—the apparent dip of the beds being caused by their oblique lamination This oblique lamination is quite a common feature of the basement beds among the sedimentary

rocks of Tertiary and Post-Tertiary dates and apt to be very misleading, on account of the outcropping of the stone, sometimes over a large area, at a decided and seemingly constant angle.

Continuing northward, a recently abandoned well-shaft was examined, approximately $2\frac{1}{4}$ miles N. by NNE. of Visáwára and showed from above-downward, 3 to 4 feet of rubbly Gáj limestone subsoil, followed by 10 feet of a brecciated laterite-conglomerate overlying 25 feet of much decomposed bedded-lava. No wonder that the owner of the well complained that he had failed to reach the water-level ! On examining the surroundings, it was discovered that the deeply-seated, decayed bedded-lava at the well-site gave place, a few hundred yards farther afield, to an exposure in the channel of a small runnel from the heights of the adjacent Anájio Dhár, of perfectly sound and undecayed amygdaoidal lava, and as the land belonged to him, the agriculturist was comforted by the opinion that he would be sure to find the underground water-level at a reasonable depth,—15 to 30 feet,—by digging down upon the spot there indicated.

Still farther north, or just about $2\frac{1}{2}$ miles N. by NNE. of Visáwára, Anájio Dhar 132 feet above the sea-level, was found to consist of a typical, hog-backed hill composed from base to summit of high-level laterite, or laterite formed *in situ*, through the transformation of a complete cap of bedded-lava. The E. slope of the hill was found to be encrusted with the undenuded remains of a deposit of miliolite-limestone, bearing numerous grains and fragments of laterite.

From Anajio Dhar, a cut across country, eastward, over ploughed fields was taken in the direction of Hathmáni Derá, the soil being manifestly derived directly from the disintegration of bedded-lavas ; and the journey was continued almost due E. in the direction of Morwara, also entirely over a region of bedded-lavas

About one mile W by WSW. of Morwara, a well-shaft sunk to the depth of over 30 feet, and abandoned after a fruitless attempt to reach the underground water-level was encountered by the roadside. Upon examination, it was found to have been dug through bedded-lavas exhibiting a curiously fissile structure, not often met with, so as to closely resemble the cleavages of a basaltic dyke. This familiar appearance must doubtless have misled the native agriculturist to select the site for his well-shaft under the mistaken expectation that he would soon secure a plentiful and perennial yield of water ;—and may be cited as a good example of the proverb that "a *little* knowledge is a dangerous thing."

Proceeding eastward to within ½ mile of Morwára, a sinuous turning SSW. was taken in the direction of Keseo, and it was observed that at a trifle over ½ mile SW. of Morwára, the undulating hilly ground thereabouts marked the boundary, -trending, thenceward from Sakhpur village near Hathiani Derá,—of the Gáj limonitic-limestone deposits overlapping the bedded-lavas of the Deccan-trap. The Gáj limestone at this spot is of the nature of an outcrop of a thin band of broken stone of the Pindáralite type overlying an unknown thickness of fossiliferous conglomerate.

The undulating downs thus formed through the overlapping of the bedded-lavas by the Tertiary or Gáj limonitic-limestone beds, gradually diminish and disappear on nearing the north end of Keseo, which stands upon an eminence of bedded-lava, but, upon descending the slope to the south of the village on the road to Pálakra, ½ mile S. by SSW. of Keseo, a hillock, crowded with clumps of robust *Euphorbia nereifolia*, exhibits a cap of beds to the total thickness of 3 or 4 feet, in slabs of a coarse, russet-coloured limestone, precisely similar in texture and lithological characters, to the Dwárka-beds shelly-limestone, so frequently met with directly overlying beds of Gaj, limonitic-limestone elsewhere. Large slabs of from 2 to 4 inches thick are available, and the hill-top is literally riddled with pits from which blocks are extracted for local use.

A wide stretch of rough hilly ground composed of bedded-lavas, with occasional cappings and plenty of drift laterite, characterises the countryside between the Keseo hillock and Palakra ; but it is worthy of special notice in this place, that at 1 mile NE. of Pálakra a small hillock is formed for the most part of a brecciated laterite-conglomerate, which frequently exhibits patches of compact unweathered stone of surpassing beauty. Samples of these were secured ; but it would be premature to form any opinion as to the uniform occurrence of the material in sufficient quantities for use as an ornamental stone without careful prospecting.

Beyond the abovenoted hillock the ground is obscured by lateritic drift, with occasional revelations of a substratum of Tertiary deposits. The latter, however, become plainly apparent at a distance of ½ mile NNE. of Pálakra ; while the gentle slope leading to the village consists of a rock-plain thickly strewed with large fragments of fine, compact Gájlimonitic-limestone of the Pindáralite type, which may also be worth while prospecting.

On the way back from Pálakra WNW. to Visáwára, it was found that the Gáj, limonitic-limestone gets gradually covered by later Tertiary

deposits belonging to the Dwarka Group of beds ; until, at ½ mile SE. of Visáwára, a deep well-shaft shows the Gáj stone at a depth of 30 ft., as the water-bearing stratum, overlaid by 12 feet of rubbly conglomerate, 8 feet of an indurated russet-coloured limestone (Dwárka), and 10 feet of subsoil and soil.

The specimens collected and registered at Visáwara Camp, are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
7-1-16.	281	Russet-coloured, Indurated Slabs of Limestone.	NNW. end of Visáwára. Overlapped by Alluvium of Talav.
7-1-16.	282	Coarse, Loose-textured, Gritty Buff-brown Limestone.	300 yds. S. by SSE. of town of Visáwára.
7-1-16.	283	Consolidated River-sand and Gravel.	N. bank of Vokala, ⅛ mile due S. of Visáwára.
7-1-16.	284	Compact Consolidated Shell-sand. Has been slightly quarried. Large exposure available.	½ mile SW. of Visáwára and ½ mile N. of Creek-mouth. Runs NW. to SE. in good exposure.
7-1-16.	285	Coral-reef Rock, (Astræan). 500 yds. or more. 1 to 2 ft. thick.	⅞ mile SSW. of Visáwára. W. scarp of Creek-mouth.
7-1-16.	286	Coral-rock, (recalcified) Near top of well-shaft.	½ m. W. of Visáwára, and ¾ m. Inland.
7-1-16.	287	Rubbly Coral-rock. ..	Immediately underlying 286.
7-1-16.	288	Arenaceous Dwárka Limestone ..	Immediately underlying 287.
7-1-16.	289	Coarse, Loosely-textured, Gravelly Sand.	2 to 3 ft. thick. Immediately overlying 285.
7-1-16.	290	Rubbly, Compact, Pale-ruddy Limestone.	10 ft. thick. Overlying 289, and forming Creek-scarp.
7-1-16.	291	Indurated, Sandy, Ruddy, Honeycombed Limestone.	15 ft. sea-scarp. Overlying 290.
7-1-16.	292	Fine, Sea-beach Sand, in large, uniform quantities.	200 yds. wide Beach at base of Sea-scarp 291.
10-1-16.	293	Highly-ferruginous, Rubbly, Concretionary, Conglomerate.	Surface and 20 ft. deep, 600 yds. E. of Visáwára.
10-1-16.	294	Coral-reef Conglomerate. Zone of Consolidated Shell-sand.	⅞ m. S. by SSE. of Visáwára. SSW. 2 ft. scarp of Creek.

Date.	Registered No.	Provisional Name	Locality and Remarks.
10-1-16.	295	Loosely-textured. Consolidated, Gravelly-rock.	Immediately overlying 294. as a thin superficial crust.
10-1-16.	296	Compact. Consolidated Shell-sand. Same zone as 294. False-bedded.	SSW. 6 ft. scarp of Creek. ¾ m. S. by SSE. of Visáwára
10-1-16.	297	Loosely-textured, Consolidated Gravel. Same zone as 295.	Overlying 296. Quarried 3 to 4 ft., for village dwellings
10-1-16.	298	Coral-reef Conglomerate. Same Zone as 296.	4 ft. Sea-scarp. 1½ m. S. by SSE. of Visáwára. Below high tide.
10-1-16.	299	Coarse. Sandy. Honeycombed, Buff-brown Limestone.	6 to 7 ft. Sea-scarp. 10 yds. inland from 298.
10-1-16.	300	Coarse, Loose, Blown Shell-sand. 1 to 2 ft. deep.	Overlying. for a few yards, No. 299.
12-1-16.	301	Gáj, Limonitic-limestone.. ..	½ m. N. by NNE. of Visáwára.
12-1-16.	302	Coarse. Shelly-limestone. Overlying Gáj Limestone.	1 m. N. by NNE. of Visáwára. Surface of Roadway.
12-1-16.	303	Altered. (laterised). Gáj Limestone-conglomerate.	2¼ m. N. by NNE. of Visáwára. 10 ft. below surface of well-shaft.
12-1-16.	304	Laterite. Partly altered by Calcareous Infiltrations.	Summit of Anájio Dhár. 2½ m. N. by NNE. of Visáwára.
12-1-16.	305	Miliolite-limestone. with contained fragments of Laterite.	E. slope of Anájio Dhár. deposited on 304.
12-1-16.	306	Fissile Bedded-lava.	1 m. W. by WSW. of Morwára.
12-1-16.	307	Ruddy. Indurated, Limestone. (Dwárka). Slabs. 1 to 2 ins.	Summit cap to Hillock ½ m. S. by SSW. of Keseo.
12-1-16.	308	Brecciated Laterite-conglomerate, with miliolitic matrix.	Small Hillock. 1⅜ m. NE. of Pálakra. Ornamental, if enough.
12-1-16.	309	Gáj. Limonitic-limestone. Superficial broken blocks.	Slope of Hillock. ¼ m. NNE. and surroundings of Pálakra.

Camp-Station XIII.—Katela.

N. Outskirts of the Village.

AT 8 A.M. on the 13th instant, tents were struck at Visáwára, and the camp was removed to Kátela, and pitched by the side of a Dharamsala on the N. outskirts of the village, which is situated about ¾ mile distant from the sea-shore.

The journey from Visáwára to Kátela was planned to cover as much untraversed ground as possible by a rapid run south-eastwardly to Pálakra and from thence ESE. for $1\frac{5}{8}$ miles to meet the cart-road leading from Morwára, SSW. to Ratari. On reaching Rátari, a course SE. by ESE. was followed *viâ* Bardia to Sirinagar, and thence S. to Kátela.

Observations by the way, were made at Pálakra as follows :—The Gáj, limonitic-limestone which was formerly noted to cover the surface surrounding the NW. of the village, was traced to tail down south-eastwardly for about $\frac{1}{2}$ mile ; but the ground immediately to the S. thereof, or ESE. of Pálakra village was found to be largely lateritic. Samples were taken and well-shafts examined 200 and 300 yards ESE. of Pálakra to show a superficial deposit of thick slabs of miliolite-base conglomerate, crowded with fragments of laterite and Gáj-limestone, overlying a deep layer of laterite-conglomerate, resting upon beds of Gáj-limestone, at a depth of 30 feet, coincident with the underground water-level.

During the traverse from Keseo to Pálakra on the 12th instant a glimpse of gleaming yellow in the distance, about $\frac{3}{4}$ mile to the SE., was obtained ; presumably occasioned by exposures on the scarp of a small stream, indicating the presence thereabouts of yellow-ochre ; which, from former experience elsewhere, was noted to occur in best development in the upper portions of Tertiary subsoil overlapping formations of laterite. It was therefore anticipated that yellow-ochre of good quality and in quantities sufficient for commercial purposes would probably be found eastward of Pálakra.

On reaching a spot about one mile E. by ESE. of Pálakra, the ground was carefully examined in a north-westerly direction, for half-a-mile, up to the banks of the yellow-scarped stream abovenoted. An abandoned well-shaft was found, sunk to a depth of 15 feet through soil merging below into greyish clay followed by an unascertained thickness of bright yellow-ochre of excellent quality. Up to the present this material lies hidden beneath a wide area of cultivated land, and has not hitherto been utilised in any way ; although similar material elsewhere has been exploited and exported to the Bombay market.

It may here be explained that the material found near Pálakra tallies precisely with the yellow-ochre of commerce in consisting of an excessively fine-textured marl, richly indued with limonite or hydrate of iron, in a pulverulent or friable condition. Large lumps of the material capable of being easily crushed into an impalpable powder of a

bright-yellow verging on orange colour, are available; and, from the indications already observed, it appears probable that a very considerable quantity exists immediately below the superficial layers of soil and subsoil; so that it would be worth while estimating the exact extent of the formation by the employment of a prospector's core-extracting boring-drill.

Yellow-ochre is much esteemed both locally and in Peninsular-India, as a basis for cheap distempers and paints, and is also largely in demand by colour manufacturers for the production, by calcination, of the popular pigment technically termed 'light-red.' It was noticed that the large lumps of the substance, excavated from the well-shaft near Pálakra and left lying exposed to the fierce rays of the sun, were much mottled and superficially streaked with patches and bands of light-red.

At a distance of 1¼ miles E. by ESE. of Pálakra, the countryside again assumes the aspect of a barren plain with sporadic patches of cultivated ground thickly strewed with fragments of laterite-conglomerate and pisolitic-laterite, and these were traced to a hog-backed ridge, 5 furlongs in length, trending from N. to S. and rising to a summit, 57 feet above the sea-level, a trifle over 1¼ miles E. of Pálakra.

On reaching the *páhlia* 1½ miles E. by ESE. of Pálakra, a turning SSW. was taken along the cart-road leading to Rátari, and here the canal from the Ger or Great Freshwater Marsh, about a mile farther NNE., was examined and found to show a bed of coarse slabs of gritty-limestone. This canal eventually discharges the surplus monsoon water on to a drainage slope, leading into the upper reaches of the Visáwára Creek, nearly ½ mile N. of Rátari.

Rátari itself is built upon a foundation of limestone belonging to the Dwárka Group of beds, which overlie the Gáj, or Miocene deposits conformably, and which were probably formed continuously during the Pliocene period and even after. These rocks were found, with occasional crusts of Pleistocene or Sub-recent miliolite to predominate all the way along the inland roadway from Rátari *via* Bardia, up to the confines of Sirinagar; but were pierced through apparently, by sundry outliers or ridge-tops of laterite; notably by a small eminence, rich in separations of iron-ore, which trends from NNW. to SSE. 500 yards W. of Bardia, and another similar outcrop about ½ mile NNW. of Sirinagar.

At Sirinagar, a compact, slabby and much cancellated Dwarka limestone, quarried superficially on the WNW. side of the village was cursorily examined; but, as it was growing late, a rapid drive was taken

southward, for a mile, to expedite the pitching of the camp at Katela.

Additions made to the State Geological Collection were registered as follows :—

Date.	Registered No.	Provisional Name	Locality and Remarks.
14-1-16	310	Laterite-Gáj-Miliolite Conglomerate.	Surface-rock. Roadway. 200 yds. ESE. of Pálakra.
14-1-16	311	Miliolite-base Conglomerate. With Laterite and Gáj pebbles. etc.	Surface-rock. 3 to 4 ft. of slabs. 300 yds. ESE. of Pálakra.
14-1-16	312	Laterite-conglomerate. with limy infiltrations from Miliolite.	Underlying 311 in well-shaft 10 ft. from surface.
14-1-16	313	Yellow-ochre. from well-shaft. ..	1 mile E. by ESE. of Pálakra.
14-1-16	314	Pisolitic Laterite. Compact ornamental stone. if enough.	Ridge NNW. to SSE., $1\frac{1}{4}$ miles E. of Pálakra.
14-1-16	315	Gritty Limestone (Dwárka ?) ..	1 mile NE. of Rátari. Bed of Canal.
14-1-16	316	Laterite. Fairly rich in Iron-ore..	500 yds. W. of Bardia.
14-1-16	317	Pale-yellow Limestone. Dwárka Group of Beds ?	100 yds. ESE. of Bardia. Slope of hillock.
14-1-16	318	Russet. Indurated. Cancellated Limestone. Dwárka Group.	50 yds. WNW. of Sirinagar. Stone on which village stands.

Having completed the trimming, registration and packing of specimens, a visit was paid to *Patel* NATHU HAJÁ'S *wari* and a new well-shaft being sunk in his grounds on the afternoon of the 15th instant. The Patel (of Kátela) provided a bullock-cart for the short journey, $1\frac{1}{4}$ miles E. by ENE. from the village ; and it was noticed that the ground for fully $\frac{3}{4}$ mile was covered by thick slabs of coarse miliolite, which extended eastward over the State Jungle-reserve there situated, but was denuded down to nil northwardly, where the underlying strata eventually became exposed on nearing the site of the well-shaft. This well-shaft, now being enlarged, showed a rubbly and earthly, limy conglomerate of a somewhat concretionary character to a depth, from the surface of 15 feet, overlying a russet, indurated and cancellated limestone reaching down to the water-level at 40 feet.

DÁYÁ LAGDHIR, the *kumbhar* of Kátela, having drawn attention to the unusual excellence of his earthenware, accompanied the writer on the following morning, the 16th instant, to Sirinagar, to point out the site from which he was in the habit of digging out his supplies of clay. This led to a careful observation of the northern surroundings of the village, where it was found that the upland surface drainage from the great Ger or Freshwater Marsh, a couple of miles to the N. and NE., collects to form a small stream running towards the NE. of Sirinagar, to be dammed up on the NW. side of the village to form a *talav* or reservoir. The bed of this talav and its N. and E. surroundings, show interesting outcrops of Gáj, limonitic-limestone of the Pindaralite type, but in fragmentary beds, overlying a deep deposit of Gaj conglomerate, which is particularly rich in typical Miocene *Mollusca*, and from which a few fossil shells, including the internal cast of a large specimen of *Strombus gigas*, were secured.

Alluvial clay, freely incorporated with dissociated grains of Gáj limonitic limestone to constitute a kind of dark-grey, plastic marl, is deposited year by year upon the bed of the affluent to the *talav*; and, when drying after the monsoon, forms a deep layer of potter's-clay, which is accounted to yield the best quality of material, on the low, southern scarp of the stream, at the NE. end of the village of Sirinagar.

Towards the NW. dammed border of the *talav*, about 200 yards N. by NNW. of Sirinagar, the russet-coloured, coarse and cancellated limestone, which was noted to be slightly quarried WNW. adjoining the village, is found to thin down into slabs, the lower beds of which are crowded with fossil shells of probably Miocene age; but the lithological characters of the stone differ so markedly from the immediately underlying beds of Gáj limonitic-limestone and its substratum of fossiliferous rubbly-conglomerate, that these beds, which, to the naked-eye, and even under the microscope, are closely similar to the much later deposits of miliolite, must be assigned to the Dwárka Group of beds :—Upper Miocene, Pliocene and probably Early Pleistocene.

At the N. end of the Sirinagar *talav*, a very old well-shaft was examined, and found to contain a puddle of water at a depth of 35 feet, issuing from clefts in a hard laterite, which is manifestly overlapped by the Tertiary deposits of the Gáj Group of beds noticed above.

On returning to Kátela betimes, the opportunity was taken to investigate the geological structure of the coastal land lying between the village and the sea-shore ;—a distance of about 6½ furlongs. It

was ascertained that the sea at low-tide reveals the presence of a very rough, gritty-conglomerate in which numerous shells of recent mollusca lie imbedded; and that this fast-forming selvage of rising-beach is covered on the shore-side by about 50 yards or so of sand, blown up inland into flat-topped ridge-like dunes, held together by growths of *Ipomœa biloba* for 100 feet or more; a low plain of consolidated sand thereafter intervenes, for about 200 yards, and is followed by a succession of higher dunes, held together by clumps of *Heliotropium ovalifolium* and a few sedges and grasses in the form of a number of closely crowded small mounds. These larger inland dunes of blown-sand slope down gently for 500 yards or more to the lower level of the cultivated fields, yielding good crops of carrots, brinjals and a few other vegetables;—as the natives do not appear to be ambitious enough to excel as market gardeners. Approaching the village there is a long, low, narrow-ridge, only 100 yards wide, of hard, gritty limestone, which was traced to extend from the S. of Rátari, past Kátela, right up to Kunchri and beyond that village for fully 1½ miles. The true nature of the stone forming the ridge, remains to be revealed by microscopical investigation; but it does not appear to be of any commercial value.

Shortly after dawn of day on the 17th instant, after perambulating the purlieus of Kátela on its southern seaward side, a traverse was made to Kunchri and north-eastward to the southern limits of the great Ger or Freshwater Marsh, and from thence westward and then southward to Sirinagar and back to camp at Kátela, thereby covering a large tract of new ground.

Observations made at intervals on the way from Katela SE. by SSE. to Kunchri, showed a superficial deposition of stone and sand, essentially similar to that already recorded with reference to the sea-board at Kátela. For example, on reaching the ancient pile, called Khimeshwar Derá, it was noticed that the sand-dunes slope to the very edge of the sea, covering a rough littoral of forming conglomerate; but that the blown-sand is here almost entirely held together, by clumps of *Heliotropium, Cyperus, Carex* and a few grasses;—the beautiful creeping *Ipomœa* being 'conspicuous by its absence.'

Passing ESE. from Khimeshwar Derá to the S. side of Kunchri, the long, low, narrow ridge of gritty limestone or shell-sand, was crossed about 200 yards SSW. of the large village, and it was found that the rock underlying this, and which outcrops on the E. and NE. of the village beyond the confines of the salt-water inlet there situated, consists of a finely textured, white to buff and sometimes ruddy, apparently azoic,

arenaceous limestone, which corresponds closely to the stone that immediately underlies the coral-reef rock and shelly limestones of Visáwára Creek-mouth, and may therefore be taken as its equivalent in this situation.

Locally called "Kunchri-stone," large slabs of the material, (which is almost shaly in structure, and therefore of but small commercial value), are dug out from the shallow deposits, obscured by a coating of alluvium, for local use,—notably on the causeway spanning the inlet on the NE. of Kunchri. Passing by these superficial excavations of Dwarka-beds limestone, the traverse was continued NNE. to Renawára and beyond, right up to the flat alluvial plains bordering the southern limits of the great Ger. Here, the westward road from Simani was followed for over 3½ miles, in the direction of Palakra, over flat fields of alluvium, sometimes thickly strewed with drift stone of a miscellaneous character.

At 1¾ miles ESE. of Pálakra, the SSE. cart-road was taken, for a couple of miles, to Sirinagar, over ground constituted for the most part of soil and stone derived from underlying limestones of the Dwárka Group of beds. Through these beds, at about ½ mile N. by NNW. of Sirinagar, a narrow ridge of about one furlong in length, and trending approximately from NNW. by NW., to SSE. by SE., protrudes, and manifestly consists of a cap of high-level laterite, bearing a deposit of laterite-conglomerate at its summit. There can be no doubt, that the laterite found at the bottom of the Sirinagar-talav well-shaft, is part and parcel of this formation.

On the 19th instant a drive was taken to the PATEL OF KATELA's garden, where a few of his friends had assembled to take tea; and the company were led by K. S. SHIVSINHJI of Sirinagar, through his own gardens and fields, to inspect a new well-shaft, ½ mile SE. of Sirinagar. Here it was found that a somewhat rubbly russet-coloured limestone presumably of Dwarka-beds age, to a depth of 15 feet, was followed by an indurated-limestone conglomerate down to a depth of 30 feet and the underground water-level. On the return journey to Katela, it was observed that the deposits abovenoted, which appear to belong to the last-formed of the Dwarka Group of beds, are covered south-westward by thick slabs of coarse miliolite-limestone.

It was decided on the 21st instant to remove the camp to Degám as the next centre of operations, and the journey there from Kátela was accordingly planned to cover as much untraversed ground as possible. To that end, the cart-road inland, was followed SE. a little

beyond the site of Khimeshwar Temple, which had previously been examined ;—on the 17th instant.

Upon this occasion it was noticed that a line of pits were being excavated about $\frac{1}{4}$ mile SSE. of Khimeshwar Temple, and somewhat less than that distance from the sea-shore. These shallow pits were found, upon being followed up, to border the coast-line almost continuously, for a distance of more than $3\frac{3}{4}$ miles in the direction of Porbandar-City, and to be desultorily worked at irregular intervals. At the Khimeshwar Dera end, solid blocks of stone are yielded at a depth of 10 feet from the surface, and are sold at the pit-mouth for Rs. 3 per hundred blocks, each roughly measuring 14 by 9 by 6 inches. The stone is a sub-recent, consolidated, shell-sand of loose and very porous texture ; but sufficiently strong to be found useful for the building of cottages and other small native dwelling-houses. At Khari Khan near Khimeshwar and Kunchri, it is of a white colour, and seen to be composed principally of the comminuted shells of recent molluscs and other marine forms of life ; but at other places, the stone grows brown or grey by the oxidation of an excess of iron which it contains.

Cuttings through the low dunes at Khari Khan, $\frac{3}{4}$ mile W. of Kunchri serve to demonstrate the true nature and origin of these formations at a glance. For a depth of about 10 feet from the surface of the blown shell-sand the pit-backs show admirable sections revealing the percolation of carbonated waters through the compacted sand in form of an elongated meshwork of cracks filled with segregations of comminuted marine shells, bound loosely and then more closely together with secondary lime. These combine to produce a vertically elongated reticulum of white stone, the meshes of which grow shorter and broader from above-downwards to a depth of 10 feet, after which the stony meshwork coalesces to form a solid mass of beds to a total depth of five feet or so. These beds vary from 6 to 9 inches in thickness, and probably originate by reason of successive breaks in accretion from season to season. The interspaces between the meshes of the upper parts is filled with only partially coherent shell-sand of a brownish colour, bearing numerous shells, principally of recent molluscs, and the entire formation, thus clearly shown to be sub-aerial, rests upon, or rather overlaps the fast-forming coarse, littoral-conglomerate seawards, and the shelly and other limestone beds of the Dwarka Group inland. The recent rocks of the coast-line at this part, are therefore of a two-fold nature :—littoral and sub-aerial in origin, and both of these overlap the much older formed

and weather-worn beds of the Dwárka Group ;—Pliocene to Pleistocene of the European Geological Record.

Although the extensive excavations bordering the sea-shore from Kunchri practically right up to Porbandar-City are nowhere deep enough to reveal exposures of the strata underlying these sub-aerial accumulations, there are fortunately a few well-shafts in the neighbourhood, where the superposition of the beds can be clearly distinguished. One of these, now being sunk, 2 miles WSW. of Bokhira, was examined and found to show a surface deposit, 6 feet thick of the sub-recent consolidated shell-sand, of a brownish-grey colour, but in all other respects similar to the Khari Khán white stone, overlying Dwarka Group beds of a compact, ruddy and somewhat splintery, apparently azoic limestone ;—comparable to that occurring on the E. and NE. of Kunchri, at the surface.

After traversing the western borders of the marine backwater and passing to the east side of Kunchri, the upper ENE. cart-road was followed to Degam. The track very soon became excessively rough and rutty, by reason of the outcrop of false-bedded, apparently azoic-sandy limestones, varying in colour from white, to pink and yellowish brown. About ½ mile W. of Degám the surface of the ground is everywhere trenched to depths of from two to ten feet, and huge slabs of stone extracted and trimmed into building blocks, which are said to be in constant demand for the foundations of dwellings. The blocks frequently measure 1½ feet in thickness ; but these are invariably constituted by layers barely exceeding an inch in thickness, more or less firmly held together by a coarse often highly ferruginous material, along which the blocks are always prone to split. When moderately sound blocks are laid with their laminæ horizontally disposed, however, the stone is accounted to be exceptionally strong and capable of withstanding enormous crushing power. Unfortunately, it is too coarse and variable in texture to be used for front elevations of urban buildings, and would not therefore realise prices to justify exportation to large centres of distribution.

Immediately underlying the deposits of Degam-stone, which is practically continuous with the essentially similar Kunchri-stone, both of which belong to the same uppermost beds of the Dwárka Group, there lies a deep but very variable deposit of richly fossiliferous conglomerate, which doubtless represents the base of the beds abovenoted and presents a Pliocene if not Post-Pliocene facies. Samples of stone from these beds were obtained from the bottom of a 30 feet deep well-shaft, ¼ mile W. of Degam.

Specimens added to the State Geological Collection are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
15-1-16.	319	Rubbly. Indurated and Cancellated Limestone. (Dwárka). Earthy, Conglomeratic-base.	Well-shaft surface. Patel Nathu Hájás Wári. 1¼ miles E. by ENE. of Katela.
15-1-16.	320	Russet. Compact. Cancellated Limestone, similar to 318.	Same locality as 319, but from 15 to 40 ft. below surface.
16-1-16.	321	Extra-good Potter's Clay. Alluvium and Gáj Soil mingled.	Surface pits, scarp of nálá, NE. side of Sirinagar village.
16-1-16.	322	Shelly-limestone. Shaloid Slabs. Lower part of 318.	NW. edge of Talav, 200 yds. from Sirinagar village.
16-1-16	323	Gáj Limonitic-limestone. Full of fossils ;—*Strombus, etc.*	Immediately underlying 322
16-1-16.	324	Laterite. Bottom of 35 ft. well-shaft.	In Talav Underlying 323.
16-1-16	325	Gritty. False-bedded Limestone.	500 yards SW. of Kátela.
17-1-16.	326	Shelly-limestone. (Dwarka) ..	200 yards SSW. of Kunchri
17-1-16.	327	Compact Limestone in Slabs. (Dwárka). Quarried for Causeway.	¾ mile NNE. of Kunchri. Underlying thin Alluvium.
17-1-16.	328	Shelly-Gravelly-Conglomerate. Exposed by erosion of nala	1½ miles NNE of Kunchri
17-1-16.	329	Compact Shelly-limestone. ..	Overlying 328
17-1-16.	330	Brecciated. Limy-conglomerate. 2 to 3 feet deep.	Surface of well-shaft, 500 yards S. by SSE. of Renáwára.
17-1-16	331	Compact Limestone. In thin slabs. (Dwárka).	Same site as 330. 4 to 10 ft. from surface.
17-1-16.	332	Compact. Shelly-limestone. ..	Underlying 331.
17-1-16	333	Gáj. Limonitic-limestone. Containing curious (fossil)? structures.	Underlying 332. 25 ft. bottom of well-shaft. 100 yards SSE. of Renáwára.
17-1-16.	334	Laterite-conglomerate. Compact, ornamental, if enough.	Narrow hillock, ½ mile N. by NNW. of Sirinagar.
19-1-16.	335	Sandy-limestone. Cancellated. 6 mile long, low Coastal-ridge.	300 yards SSW. of Kátela and ⅝ mile from Sea-shore.
19-1-16.	336	Sandy-limestone. In slabs. ..	½ mile ENE. of Kátela

Date.	Registered No.	Provisional Name	Locality and Remarks
19-1-16	337	Rubbly, Russet Limestone. Surface. 15 ft. deep.	New well-shaft of K. S. Shivsinhji. $\frac{1}{2}$ mile SE. of Sirmagar.
19-1-16	338	Indurated Limestone from Rubbly Conglomerate (Dwarka).	Underlying 337 at depth of 30 ft water-level
21-1-16	339	Sub-recent Consolidated Shell-sand. 10 to 15 ft deep.	Khári Khár, $\frac{3}{4}$ mile W. of Kunchhi
21-1-16	340	Partially Consolidated Shell-sand	Superficial and inter-reticular portions of 339
21-1-16	341	Fossils from Shell-sand ..	.. Same site as 339, 340.
21-1-16	342	Compact Shelly-limestone.	.. Overlapped inland by 339
21-1-16	343	Consolidated Shell-sand. Loosely textured. Sub-recent	2 miles WSW. of Bokhira 6 ft thick Surface of well-shaft.
21-1-16	344	Compact. Splintery Limestone ..	Overlapped by 343
21-1-16	345	Compact. White Limestone. Surface. False-bedded Slabs.	$1\frac{1}{2}$ miles WSW of Degám On roadside.
21-1-16	346	Compact. White Limestone. 5 ft deep. Surface Slabs.	$\frac{1}{2}$ mile W of Degám Largely quarried.
21-1-16	347	Richly Fossiliferous (Dwárka) Limestone. Underlying 346.	Well-shaft bottom. 30 ft $\frac{1}{4}$ mile W. of Degám.

Camp-Station XIV.—Degam.

E. side of the Town.

UPON arrival at Degám, considerable difficulty was experienced before tents were pitched ; as the expert "*Pharas*" or tentman who had been attached to the camp was withdrawn, and substituted by another who did not understand his work satisfactorily. It was therefore dark before things could be got into good order, and the best part of the day following,—the 22nd instant,—was taken up with minor matters ; so that there was just barely time enough in which to pay a visit to the salt-pans of the State, $1\frac{1}{4}$ miles to the NW. of Bokhira.

Covering an area of about $\frac{1}{2}$ mile in length by $1\frac{1}{2}$ furlongs wide at its broadest part, the State salt-pans are conveniently situated on

the barren, flat border of the backwater or salt-water waste, which has its inlet at Porbandar Creek and broadens out north-westward to terminate in a shallow swamp to the north-east of Kunchri. Porbandar Creek itself, swerves round the City south-eastward to eventually join the vast depression known as the Great Salt-waste, which stretches far and wide south-eastwardly to Navibandar and beyond.

Alluvial deposits obscure the bed of the backwater in the region of the salt-pans; but, from observations of outcrops on the roadway north-westward from Bokhira, it is at least certain that the underlying strata belong to the Dwárka Group of beds, equivalent with those that stretch NW. to the confines of Kunchri and N. to Degám. The salt-pans are projected after the fashion of native wheat-fields, into a number of rectangular beds or shallow tanks, divided by channelled mud-banks or aqueducts; and the brine from the backwater is collected at high-tide into a well-shaft or reservoir adjoining, from whence it is raised as required by leathern buckets and bullock labour, to be allowed to flow by gravitation into the prepared pans. Evaporation, by the fierce rays of the sun does the rest; and, so soon as a sufficiency of salt has been precipitated, usually in caky layers of about an inch or two in thickness, it is simply gathered by handfuls, rinsed in the remaining brine, and thrown into heaps, to be gathered for the market.

Samples of the salt, as well as of the mother-liquor, were taken for analyses, with a view to determining whether it would be possible to profitably purify the former, or utilise the latter for the separation of magnesium chloride. It may however, at once be stated, that it would be a matter of extreme difficulty to collect a sufficient quantity of the mother-liquor left behind, after the salt for market is removed, under existing circumstances.

On the 24th instant, an excursion was planned and successfully carried out to explore the whole of the region lying north of Degám that had hitherto remained untraversed. A drive was taken WNW. by NW. for a distance of 3 miles to Renáwára, and notes by the way were made, showing that the white arenaceous limestone of the Dwárka Group, so plentifully present at the surface surrounding Degám, gradually thins down in the direction of Renáwára, where the superposition of strata was well exemplified by a well-shaft $\frac{1}{4}$ mile ESE. by E. of the last-named village. Hereabouts, the surface to a depth of 4 feet, was seen to consist of beds of a richly fossiliferous limestone, clearly forming the lowermost portion of the Degám-stone deposits. Below this there

could be identified about 5 feet of a coarse conglomerate, largely composed of fragments of Gáj limonitic limestone, resting upon 4 feet or so of more or less compact limonitic limestone of the Pindáralite type, but too much broken and irregularly jointed to be of any commercial value.

From Renáwára a NNE. course was taken along the road to Bhárwára for about a mile; but, upon reaching a place $\frac{1}{3}$ mile N. by NNE. of Renáwára, the surface of the ground was found to exhibit a distinctly Miocene facies, and it was therefore fortunate that a small disused well-shaft was found at hand showing a very richly fossiliferous stratum of shelly, limonitic-limestone (of which a fine museum specimen was secured), overlying a band of compact Gáj limestone of the Pindáralite type.

In consideration of the circumstance that these finely textured bands of ornamental stone, namely, the dolomitiferous Pindáralite and the kindered Bharwárálite, are invariably developed, in commercial consequence, only locally, it would be desirable, wherever they are detected, to make use of a prospector's core-extracting drill ; as it is more than likely that when placed upon the market both Pindáralite and Bharwárálite would speedily find favour by reason of their intrinsic merits ;—to wit, their pleasing tones of pale to rich yellow, orange and cinnamon hues ; the ease with which they can be delicately carved ; and, the light polish or fine matt surface which can be most readily imparted to the materials under consideration.

Continuing NNE. along the cart-road to Bhárwára up to the nether alluvial flats of the Ger or Freshwater Marsh, a cut across the pathless countryside was taken in the direction of Simáni, and an opportunity afforded for collecting additional good specimens of Miocene corals from the zone exposed by a cutting nearly opposite to the Bábadeshwar Temple on the made-road leading from Degám to Bhárwára and beyond. Thereafter, a rough cart-track was followed south-eastwardly to the village of Pándáwadar, necessitating a short traverse over laterite ground, which it will be remembered was formerly noticed as an extension of the lateritic ridge, trending W. from the so-called "iron-mines" site in the vicinity of Bákharla.

Approximately $1\frac{1}{4}$ miles SE. of Bábadeshwar Temple, the lateritic ridge was observed to be overlapped by an outcrop of thick slabs of stone dipping at an angle of sometimes as much as 45°. Upon closer and careful examination, these slabs were found to be false-bedded, and to be composed of a dark buff-grey finely textured limestone inter-

laminated with thin coarser, shelly, fossiliferous layers, and manifestly belonging to the lower beds of the Degám-stone or Dwárka Group This outcrop of stone was traced southward to the village of Pándáwadar, where, at the talav to the SE., it was found to overlie a tolerably thick bed of stone closely crowded with the shells of bivalve molluscs presenting a distinctly Pliocene facies.

Returning SW. to Degám, a few well-shafts were examined at intervals on the way and it was noted that with but slight variations of no importance the whole of the countryside was practically covered to varying depths with soil and subsoil, diversified by patches of bare rock belonging to the Dwarka Group of beds, typically represented by false-bedded Degám-stone or whitish sandy-limestone in tolerably thick slabs with alternating laminæ of fine and coarser texture These superficial deposits were generally found to pass insensibly below into an appreciably thick littoral deposit of recalcified fossil shells, (mainly lamellibranchiate), of the nature of a base of conglomerate, conformably overlying the limonitic limestone strata of the Gáj Group or marine Miocene.

Tents were struck at Degám on the morning of Tuesday, the 25th January, 1916, and the return to Porbandar headquarters so arranged as to complete the examination of the whole of the State lying to the north of the main made-road from the City to Ránáwáo. Old ground was covered by a rapid drive to Pándáwadar, and the south-easterly cartroad, very rough and rutty at places, was thereafter followed as far Kolikhara. At Kolikhara, ¼ mile NNW. of the village, a 15 feet deep well-shaft showed that the limestones of the Dwárka Group had diminished markedly; leaving only superficial layers of conglomerate, overlying a deposit of coarse laterite-conglomerate.

Proceeding SE. by SSE. partly along cart-tracks but mostly over pathless ground, the shelly limestones of the Dwárka Group were found to predominate at the surface; but, upon reaching the old site of Arniála, 1¼ miles SSE. by SE. of Kolikhara, an appreciable deposit of much honeycombed miliolite was observed to cover the Dwárka limestones, which were exposed by the scarp of a stream ½ mile SE. of old Arniála.

Crossing over the Railway-line to the ruins of Rájpura, (near by which the southward course of the abovenoted stream, trending SE. into the Great Southern Salt Waste, was found to be fairly full of water and appropriated by groups of *dhobies*), the shelly, compact, but slab-like limestones of the Dwárka Group, frequently false-bedded, and apparently dipping at decided angles, once more characterised the

outcrops at the surface, and continued to predominate WSW. into the very heart of the City of Porbandar.

Specimens added to the State Geological Collection Register, are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
22-1-16	348	Evaporated Salt	Salt-pans 1¼ miles NW. of Bokhira.
24-1-16	349	Fossiliferous. Gáj Limestone. ..	¾ mile N. by NNE of Renáwára
24-1-16	350	Limonitic-limestone. Pindára type.	Underlying 349.
24-1-16	351	Dark, Compact Limestone. In fissile honeycombed Slabs. (Dwárka).	1¼ mile SE. of Bábadeshwar Temple near Simáni.
25-1-16	352	Compact. Shelly-Limestone. Dwárka Group of Beds.	500 yards ESE. of Pándáwadar. Underlying Degám-stone of Talav.
25-1-16	353	Indurated. Buff Limestone. (Dwárka) In large Slabs.	Low Eminence. 1⅛ miles SE. by SSE. of Pándáwadar.
25-1-16	354	Limestone-conglomerate. Dwárka Group Base.	Top of 15 ft. well-shaft. ½ mile NNW. of Kolikhara.
25-1-16	355	Coarse Laterite-conglomerate. ..	Underlying 354.
25-1-16	356	Miliolite-base Conglomerate. ..	¼ mile ESE. of Amiála.
25-1-16	357	Deep-ruddy. Honeycombed Limestone. (Dwárka).	Scarp and bed of stream Immediately underlying 356

DIGEST OF DIARY.

February, 1916.

AS ALREADY NOTIFIED, a return to headquarters,—after a camping tour of over 3½ months,—was effected on the 25th January, 1916, and the remainder of that month was very fully occupied with unpacking, reparcelling and arranging the large collection of samples secured for the State Geological Collection.

During this period of turmoil, an unexpected visit to Porbandar brought the representative of THE INGERSOLL-RAND COMPANY, of

Forbes Buildings, Home Street, Bombay, to these Offices, in answer to an inquiry addressed to the London Office of the firm, for particulars concerning quarrying, mining and road-making machinery.

From this interview it was ascertained that stone-breaking and sorting machines for road-making could best be obtained from MESSRS. MARSHALLS, LTD., of Bombay; but that in the event of prospecting, quarrying and mining installations being required by the State at any time, the INGERSOLL-RAND COMPANY, perhaps the largest and best organisation of the kind in the world, would be prepared at any time to send an expert engineer to ascertain requirements and submit specifications.

There can be no doubt, that in order to utilise the valuable stone resources of the State (detailed records of which have appeared from time to time in these reconnaissance reports) to the best advantage, it would be imperative to take a speedy initiative in placing matters on a thoroughly sound commercial basis, and to that end it would be necessary to provide plant for prospecting, extracting and manipulating crude materials and of conveying them expeditiously at a minimum of expenditure to centres of consumption and distribution. It need scarcely be pointed out that such a course of procedure, could only be satisfactorily carried out as a State speculation or by the formation of a sufficiently capitalised Joint-stock Company.

From the Register of Rocks, recorded by instalments in these monthly reports, it will be gathered that a very vast and varied series of sound merchantable stones is more or less readily available for exploitation. These will be duly classified and systematically described with special reference to their commercial value, separate uses, physical properties and composition, upon the termination of the present reconnaissance survey; but, for the present, it may be noted that they include: 1°. All the most valued varieties of economic stones known to exist, suitable for the erection of palaces, public-buildings and dwelling-houses. 2°. Stones of exceptional strength and durability suitable for foundations, steps, landings, bridge-piers, dock and harbour construction and the making of permanent highways. 3°. Ornamental stones selected from the abovenoted classes, suitable for being carved or polished, a few of which are of such rare occurrence as to justify them in being described as unique.

To place these commodities firmly upon the markets of India, a good many of them will require prospecting by modern methods,—ordinary and core-drilling and so forth; while the majority would call

for pneumatic or electric drilling and extracting machinery, crushing and nidging machines, and, in course of time, the more costly plant for polishing.

The cost of conveyance from the sites to the port, which is at present an almost insuperable difficulty, (with the single exception of the Ranáwáo sites) could best be minimised by the employment of motor traction wagons ; while exorbitant freights can only be avoided by the chartering or purchase of a small fleet of cargo boats, and the installation where needful of either permanent or temporary landing places.

It is clear that unless these or a modification of these arrangements are instituted, either by the establishment of a State Industrial Department, or the formation of a duly authorised and sufficiently capitalised Company, it would be futile to expect more than a very modest increment of Revenue from the stone resources of the State ; and now that enterprising builders and architects are commencing to "wake up," in anticipation of a cessation of European hostilities, it is surely time that some decisive move should be made in the matter.

On the 11th instant MR. SYDNEY SYMONS of the Porbandar Cement Works kindly furnished results of a first lot of analyses by MR. R. E. J. M'CULLY, as follows." :—

"*Porbandar-Stone or Miliolite-limestone.*—

Water	·02
Carbonic acid	41·96
Silica	1·96
Oxide of Iron and Alumina	1·50
Lime	51·33
Magnesia	1·98
Alkalies	1·25
	100·00

Typical "Barda-Hills Stone" or Granophyre.—

Loss on Ignition	·68
Silica	71·54
Oxide of Iron and Alumina	9·48
Lime	2·01
Magnesia	·43
Alkalies	5·80
	100·00

Mother Liquor after extraction of Sodium Chloride from Sea-Water Porbandar Salt-pans.

Specific Gravity .. .. 1·300

Magnesium Chloride, 23·3 per cent. or equivalent to 48·6 ozs. per Gallon.

This memorandum of analyses is here entered for future reference if required. For the present, however, it may be observed that the miliolite is shown to be a practically pure calcareous stone, with only sufficient silica to enhance rather than detract from its strength as building material ; while the percentage of iron and alumina is so low, as to be scarcely sufficient to cause a very slight coloration, to a very pale buff, by oxidation and hydration of the former, and to barely appreciably harden the texture by the presence of the latter.

On the other hand the preponderance of silica in the granophyre fully confirms the claims made for the material on the score of durability and great strength ; but, with reference to the latter property, optical determinations to show the precise relative positions of the units of free silica or quartz, to those of the silicates of alumina, etc., called felspars, are, of course additionally desirable.

With reference to the third analysis ; namely, the estimation of magnesium chloride in the mother liquor collected from the Porbandar salt-pans :—It may be noted that DR. DITTMAR'S generally accepted analysis of normal sea-water gives the percentage of magnesium chloride at 10·878 ; so that the quantity of that salt present in the sample under consideration is unquestionably very high. Unfortunately however, the insuperable difficulty of securing sufficient supplies up to standard of sample, coupled with expensive technical processes, and outlay for the installation of a costly plant, would render any project for the separation of the salt on a commercial scale extremely hazardous.

A considerable portion of the writer's time was occupied in piecing together evidence concerning the geological structure of contiguous regions which by stress of circumstances, in traversing circuitous routes had to be held over from time to time ; but happily, by the end of the second long traverse, sufficient data had been gathered to furnish coherent material for the second Quarterly Report.

On the 16th instant, the long deferred Photomicrographic Apparatus, made by MESSRS. W. WATSON & SONS, LD., of High Holborn, London, duly arrived, and having been unpacked and examined, was carefully stored away, pending the preparation of rock-sections for the microscope, upon the final return of the writer from reconnaissance or field work

This improved modern appliance will require to be firmly mounted upon a strong table, and, in conjunction with a properly illuminated microscope, will enable the operator to secure the best possible results, in making clearly focussed figures, illustrative of the microscopical structure of the various petrological specimens collected, with absolute fidelity, down to the most minute of details.

Special additions to the State Geological Collection during the current month are as follows :—

Date	Registered No.	Provisional Name	Locality and Remarks
19-2-16	358	Miliolite-limestone, 2nd to 3rd Grade. 2½ to 3 in. Slabs.	Ádatiána Heights, Bhoyrawari Plot. Kasam Aboo's Quarry. No. 3.
19-2-16	359	Miliolite-limestone. 2nd Grade. 1st Quality. Ordinary Building-blocks.	Ádatiána Heights. Bábulwari Plot. Kasam Aboo's Quarry. No. 22.
19-2-16	360	Miliolite-limestone, 2nd Grade, 1st Quality. Ordinary Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Kasam Aboo's Quarry. No. 7.
19-2-16	361	Miliolite-limestone. 1st Grade. 1st Quality. Large Building-blocks.	Ádatiána Heights Járwari Plot Velji Lavji's Quarry. No. 259.
19-2-16	362	Miliolite-limestone. 1st Grade, 1st to 2nd Quality. Ordinary Building-blocks.	Ádatiána Heights, Bhoyrawari Plot. Kasam Aboo's Quarry No. 4.
19-2-16	363	Miliolite-limestone. 2nd Grade. 1st Quality. Flooring slabs. etc	Ádatiána Heights. Bhoyrawari Plot. Oomar Jamal's Quarry. No. 1.
19-2-16	364	Miliolite-limestone. 1st Grade. 1st Quality. Large Building-blocks.	Ádatiána Heights Kundlawari Plot Hajji Esmail's Quarry, No. 125.
19-2-16	365	Miliolite-limestone 2nd Grade, 2nd Quality. Thin. hard slabs.	Ádatiána Heights, Bhoyrawari Plot. Vali Mahommed Aboo's Quarry, No 2.
19-2-16	366	Miliolite-limestone. 1st Grade, 1st Quality. Large Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Velji Lavji's Quarry. No. 5
21-2-16	367	Miliolite-limestone, 1st Grade, 2nd Quality. Ordinary Building-blocks.	Ádatiána Heights. Járwari Plot. Kasam Aboo's Quarry. No. 119.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
21-2-16	368	Miliolite-limestone 1st Grade, 2nd Quality. Large Building-blocks.	Ádatiána Heights. Kasam Aboo's Quarry. No. 44
21-2-16	369	Miliolite-limestone. 2nd Grade, 1st Quality. Large Building-blocks.	Ádatiána Heights, Bábulwari Plot. Oomar Mohammed's Quarry. No. 25.
21-2-16	370	Miliolite-limestone, 2nd Grade. 1st Quality. Ordinary Building-blocks.	Ádatiána Heights. Shikhar Plot. Nanji-Virji's Quarry. No. 100.
21-2-16	371	Miliolite-limestone. 2nd Grade. 2nd Quality. Flooring slabs, etc.	Ádatiána Heights. Bábulwari Plot. Kasam Aboo's Quarry. No. 21.
22-2-16	372	Miliolite-limestone. 1st Grade. 2nd Quality. Large Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Kasam Aboo's Quarry, No. 4.
22-2-16	373	Miliolite-limestone. 1st Grade 2nd Quality. Large Building-blocks.	Ádatiána Heights. Tankawari Plot. Nanji Virji's Quarry, No. 83.
22-2-16	374	Miliolite-limestone. 1st Grade, 2nd Quality. Large Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Nanji Virji's Quarry, No. 13.
22-2-16	375	Miliolite-limestone. 1st Grade, 2nd Quality. Large Building-blocks.	Ádatiána Heights, Ránwari Plot. Noormohammed Abdurahman's Quarry. No. 37.
22-2-16	376	Miliolite-limestone. 2nd Grade, 1st Quality. Flooring slabs, etc.	Ádatiána Heights. Bhoyrawari Plot. Velji Lavji's Quarry, No. 5.
22-2-16	377	Miliolite-limestone. 1st Grade, 1st Quality. Ordinary Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Nanji Virji's Quarry. No. 9.
23-2-16	378	Miliolite-limestone. 1st Grade, 1st to 2nd Quality. Large Building-blocks.	Ádatiána Heights, Bhoyrawari Plot. Nanji Virji's Quarry, No. 12.
23-2-16	379	Miliolite-limestone. 1st Grade, 1st to 2nd Quality. Large Building-blocks.	Ádatiána Heights. Bhoyrawari Plot. Nanji Virji's Quarry, No. 15.
23-2-16	380	Miliolite-limestone. 2nd Grade, 1st Quality. Large Building-blocks.	Ádatiána Heights, Bhoyrawari Plot. Oomar Jamal's Quarry, No. 19.

Date.	Registered No.	Provisional Name	Locality and Remarks.
23–2–16	381	Miliolite-limestone 2nd Grade, 2nd Quality Ordinary Building-blocks.	Ádatiána Heights. Bábulwari Plot. Kasam Aboo's Quarry, No. 20.
23–2–16	382	Miliolite-limestone 2nd Grade. 2nd Quality. Ordinary Building-blocks.	Ádatiána Heights. Bábulwari Plot. Kasam Aboo's Quarry, No. 23.
24–2–16	383	Miliolite-limestone. 2nd Grade, 2nd Quality. Ordinary Building-blocks.	AdatiánaHeights. Babulwari Plot. Ahmed Ali's Quarry, No. 24.
24–2–16	384	Miliolite-limestone. 2nd Grade, 1st Quality. Ordinary Building-blocks.	Ádatiána Heights. Ránwari Plot. Noormohammed Abdurahman's Quarry. No 27
24–2–16	385	Miliolite-limestone 3rd Grade, 2nd Quality. Coarse, thin Slabs.	Adatiána Heights. Ránwari Plot. Noormohammed Abdurahman's Quarry. No. 28.
24–2–16	386	Miliolite-limestone. 1st Grade, 2nd Quality. Ordinary Building-blocks.	Ádatiána Heights. Bábulwari Plot. Nanji Virji's Quarry, No. 32.
24–2–16	387	Miliolite-limestone. 2nd Grade, 2nd Quality Blocks and Slabs.	Ádatiána Heights Bábulwari Plot. Nanji Virji's Quarry. No. 32.
25–2–16	388	Miliolite-limestone 2nd Grade. 1st Quality Large Building-blocks.	Ádatiána Heights. Ránwari Plot. Noormohammed Abdurahman's Quarry No 37
25–2–16	389	Miliolite-limestone. 3rd Grade. Thin closely laminated Slabs	Ádatiána Heights. Nevrawari Plot Oomar Mohammed's Quarry. No 38.
25–2–16	390	Miliolite-limestone. 2nd Grade, 2nd Quality. Good. large Slabs.	Ádatiána Heights. Piprawari Plot. Velji Lavji's Quarry. No. 61.
25–2–16	391	Miliolite-limestone. 1st Grade. 2nd Quality. Large Building-blocks.	Ádatiána Heights. Piprawari Plot. Velji Lavji's Quarry, No. 62.
28–2–16	392	Miliolite Limestone. 3rd Grade. Hard, thin. Flooring-slabs.	Ádatiána Heights. Tankawari Plot. Noormohammed Abdurahman's Quarry. No. 76.

DIGEST OF DIARY.

March, 1916.

ARRANGEMENTS having been made for the printing of a summary of these reports with the Damodardas Printing House of Rájkôt, galley-proofs of a first instalment of the "First Quarterly Report on the Economic Geology of Porbandar State" were received, revised and returned to the printer on the first day of this month. These were subsequently revised for the third time, passed for press, and finally completed in the form of eight consecutive pages of letterpress by the 20th instant; when also a further instalment of eight pages of matter came to hand for a first revision.

The first day of this month was also signalised by the visit to Porbandar of the AGENT TO THE GOVERNOR OF BOMBAY for Káthiáwár, upon whom the writer called to pay his respects; while upon the following day the Administrator with the Agent to the Governor paid a visit of inspection to the headquarters of the Geological Survey.

The work of dealing effectively with the large series of blocks and boulders of miliolite-limestone and of granophyres and other economic stones secured for the State Geological Collection, demanded and received the largest moiety of attention from the beginning up to the middle of the current month; and, in addition to the proper trimming and shaping of museum specimens, a goodly series of new samples were duly registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
1-3-16	393	Miliolite-limestone. 1st Grade. 2nd Quality. Large Building-blocks.	Ádatiána Heights, Kundlawari Plot. Hajji Esmail's Quarry, No. 128.
1-3-16	394	Miliolite-limestone. 2nd Grade. 2nd Quality. Flooring Slabs.	Ádatiána Heights. Tankawari Plot. Nanji Virji's Quarry, No. 79.
1-3-16	395	Miliolite-limestone. 2nd Grade. 2nd Quality. Large Building-blocks.	Ádatiána Heights. Tankawari Plot. Nanji Virji's Quarry, No. 81.
3-3-16	396	Miliolite-limestone. 2nd Grade. 1st Quality. Large Building-blocks.	Ádatiána Heights. Tankawari Plot. Nanji Virji's Quarry, No. 82.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
3-3-16	397	Miliolite-limestone. 2nd Grade. 1st Quality. Large Building-blocks.	Adatiána Heights, Tankawari Plot. Nanji Virji's Quarry No. 84.
3-3-16	398	Miliolite-limestone. 2nd Grade. 2nd Quality Large Building-blocks.	Ádatiána Heights, Shikhar Plot Nanji Virji's Quarry, No 100.
3-3-16	399	Miliolite-limestone. 2nd Grade. 2nd Quality Large Building-blocks.	Ádatiána Heights, Bhimkot Plot. Noormohammed Abdurahman's Quarry, No. 162.
3-3-16	400	Miliolite-limestone. 3rd Grade. 1st Quality. Large Building-blocks.	Ádatiána Heights, Shikhar Plot Nanji Virji's Quarry, No. 109

The completion of the Second Quarterly Report on the 7th instant, followed by the colouring of the Geological Chart so as to indicate the boundaries of the various formations and noteworthy sites for economic products, over the entire region north of Porbandar City, occupied a considerable portion of the writer's time up to the 12th instant.

Active preparations were made during the ensuing days, for a prolonged traverse, to cover all unsurveyed ground south of the City of Porbandar. To that end, tents were sent in advance on the 14th instant to the town of Cháya, and everything having been satisfactorily packed, the writer and staff proceeded to the camp, early in the morning of the 18th instant.

Camp-Station XV.—Cháya.

About 500 yards E. of the Town.

ON THE WAY to Cháya, it was noted that the main outcropping stone consisted of exceedingly rough and rubbly consolidated shell-sand, belonging to the Dwárka Group of presumably Pliocene beds, diversified by flagstones, belonging to the same formation, immediately underlying the rubbly rock; while both were occasionally obscured by thin deposits of coarse miliolite-limestone. At Cháya itself the flagstones, frequently false-bedded, predominated at the surface; and the numerous well-shafts in the neighbourhood of the town, showed from 15 to 20

feet in thickness of these tough and strong arenaceous shelly-limestones, often in solid slabs of over 12 inches in thickness; but unfortunately far from uniform in texture; coralliferous at parts, shelly and coarsely conglomeratic, and finely textured at others. These drawbacks either singly or in conjunction, it need scarcely be pointed out, unfit an otherwise very valuable building stone for commercial purposes.

On the morning of the 19th instant, a special survey was taken of the locally famous quarries from which enormous quantities of material known as "Cháya Stone" are annually extracted for ordinary building purposes. A drive was taken for about half-a-mile in a southerly direction from the camp, over a stretch of salt-marsh alluvium, which is deeply swamped during the monsoons, to the base of the summit, of a 66 feet high, (above datum), hill; which forms the highest part of a long sub-coastal ridge, literally riddled with deep pits, like huge bottle-shaped oubliettes, descending, sometimes 60 feet, into the " bowels of the earth."

It was found upon detailed examination, that the whole of this high ridge, from base to summit, consists of one kind of stone only, a somewhat peculiar kind of limestone, which rests upon a foundation of hard, flaggy consolidated shell-sand continuous with the beds upon which the town of Cháya stands; and, as a few of the pits have been excavated to the depth of nearly 60 feet, it may be presumed that the bottom stone represents the base of the deposit.

The quarry workings are reached by means of dangerous-looking flights of country-made rough wooden ladders; and up these frail footholds, come women and even small girls and boys, each bearing loads of one or two building blocks, from $\frac{1}{4}$ to $\frac{1}{2}$ cwt., upon their heads. It was ascertained that the stone varies from place to place, both vertically and horizontally, all of which however are more or less perforated by small cylindrical channels filled with brownish earthy matter, which occasionally becomes indurated. In texture, the stone is uniformly much more finely grained than the more valuable miliolites of the Ádatiána Heights; but even its best and most compact varieties do not admit of being carved, for reasons which will doubtless become apparent when examined under the microscope.

The stone towards the base of the deposit is generally more coarsely channelled with perforations and less coherent than that from the central portions of the deposit. It is also less compact and more porous; and, instead of being white, acquires a brownish-grey colour. About 25 out of nearly 100 quarries were in active operation on the 19th March, 1916: and it was elicited, that the stone has been regularly quarried at these

sites for about half-a-century, and exclusively consumed for the erection of minor dwelling-houses in the State. Ordinary building blocks, 12 by 12 by 6 inches in dimensions of the best average qualities, are sold at the pit-mouths at Rs. 5-8 annas per 100 blocks; but prices are stated to vary and are not regulated by the quality of the stone, but simply to recompense the quarry-labourer.

It may be noted in passing, that the usual routine of camp-work consists in trimming, packing, provisionally naming and registering samples collected on the day following their collection ; and of marking all important geological boundaries and peculiar outcrops upon the chart. When the collection happens to be either a large or difficult one to deal with,—in preparing suitable chips from each sample for future laboratory research,—a second day is needed to accomplish the work in camp.

On the 20th instant, the writer was reminded, that carts and men could not be procured for field-work, as it was the closing day of the "Hindu Holi Holiday"; while on the day following,—a kind of Hindu "Saint-Monday" it was additionally declared to be a "Parsi Holiday"! The writer's work, however, was continued without interruption, as reports had unavoidably, through excess of materials collected, fallen slightly in arrear.

All samples having been satisfactorily dealt with, and a second instalment of printer's proofs of the First Quarterly Report having been revised and returned, a couple of bullock-carts were hired to accompany the writer and assistant in traversing the coastal and sub-coastal regions within reasonable reach of the camp at Cháya, on the 22nd instant.

The swamp, now dry, which forms a diverticulum on the west side of the town, up to the rear of the Geological Survey Headquarters on the SE. side of the City of Porbandar, was examined, and found to be spread over by a deposit of from 1 to 3 feet of grey, saliniferous alluvial mud ; which, on the less salty upper margins of the swamp, about 200 yards SSW. of Cháya's 'Rabari Nes' or shepherd's quarters, is excavated to a depth of only one foot, to yield a coarse clay strong and plastic enough to be fashioned and kilned into native roofing-tiles.

Farther south-eastward, or, more precisely ½ mile SE. of Cháya a large area of ground has been excavated and dammed off from the salt-water swamp in such a way as to form a reservoir for the freshwater higher-level drainage. This place is known as the "Balvi Talav" or "Báwá-ka-Mat"; and the alluvium combined with the decayed and disintegrated shelly-limestone upon which it is deposited forms an

appreciably deep layer of marly clay at the SW. end of the *talav,* which is much esteemed by local potters for making chatties and other earthenware.

It appears to be a pity that these native potters or *kumbhars,* the majority of whom are skilful 'throwers', do not combine to establish a well-regulated and comprehensive pottery. Each village supports at least one of these expert craftsmen; and, if they could only be got together and properly organised, provided with improved tools or even machinery, and instructed in the rudiments of preparing standard clays, glazes and of 'firing,' the wares scientifically which they already know so well how to fashion by hand labour, it may be anticipated that the day would not be far distant when India would become independent of the enormous supplies of household china and earthenware, annually imported into her warehouses and bazaars.

Crossing over the salt-swamp to the base of the quarry-site ridge, ¾ mile S. of Cháya, the low scarp of stone there found bordering the swamp, was found to consist of a false-bedded deposit of coralliferous and shell-sand limestone unquestionably belonging to the Dwárka Group upon which Cháya is built. Ascending the hill-slope, these nether beds are found to be overlaid by the Cháya-stone, the uppermost exposed parts of which, at the highest summit of the ridge, are much hardened by sunbaking, and so rubbly, as to be commercially worthless.

Following the steeply inclined track over the quarry-ridge in a southerly direction towards the sea-shore, a second but much lower ridge is found intervening, and also parallel with the coast-line. The summit of the highest part of this ridge was formerly pierced and quarried for stone, of which a tolerably large quantity was at one time extracted in the form of building-blocks, a goodly number of which still lie scattered around the pit-mouth. This abandoned quarry, situated about 1¼ miles S. of Cháya is locally known as Mithi Khán, and the stone is manifestly of the nature of a soft and porous sub-aerially consolidated sand; --the relic of a former dune, upraised along with its underlying stratum of beach to its present position 2½ furlongs from the margin of the sea.

At the base of the Mithi Khán elevation, about 200 yards SW. of the excavation, the underlying strata outcrop in form of large blocks of flagstone, composed of both finely and coarsely comminuted shells, corals and other organic remains firmly compacted with an abundance of siliceous sand, and corresponding in all essential details with the Dwárka Group limestones of Cháya. This material is locally and misleadingly called a black-stone or *kálá-páná*; and from its convenient

situation, was partially utilised for building the walls surrounding the Porbandar Ráj-Máhál or Palace of the MÁHÁRÁNA SAHEB. Although very tough and strong, available in blocks of large size and locally most acceptable for the purpose to which it has been applied, the stone is so variable, almost from yard to yard horizontally and from inch to inch vertically that it cannot very well be included in the category of the commercial stones of the State.

A curious phenomenon, worthy of notice in this place is, that between the Mithi Khán ancient sand-dune, and the present-day dune of blown-sand skirting and sloping down to the sea-level, there is a tolerably wide channel, which, during the monsoon is said to be flooded into a deep temporary river. Into this channel the limy detritus from the adjoining calcareous ridge is periodically swept to settle down, become dry and finally sunbaked, so as to produce a *natural chunam,* called *dorá-mutty* by the natives, and desultorily dug out when wanted, for whitewashing their dwellings.

The sand-dunes bordering the sea-shore from the Raj Mahál, past Cháya and right up to Adodar, form a continuous, practically unbroken, low, flat ridge mostly held together by bunches of sedges and grasses, and the sand generally forms a gently sloping beach down to low-water mark, where it terminates in an outcrop of big breakers of the shelly and arenaceous limestone that dominates this portion of the coastal countryside.

Specimens gathered during the sojourn at Cháya and added to the State Geological Collection are :—

Date.	Registered No	Provisional Name	Locality and Remarks
19-3-16	401	Cháya-limestone. Indurated and Cancellated. Summit surface.	¾ mile S by SSW of Cháya. Top of Munza Laxman's Pit.
19-3-16	402	Cháya-limestone. Greyish. Finely Textured but not very Compact, with branched Perforations.	Same site as 401. At depth of 20 feet, in Vasrám Somji's Pit
19-3-16	403	Cháya-limestone. Greyish False-bedded. Less coherent than 402. Much perforated.	Same site as 401 At depth of 50 ft. in Báwá Virger Jasmatger's Pit.
19-3-16	404	Cháya-limestone. White. Compact. Best-quality Stone.	Same site as 401. Near top of Ditá Meghá's Pit.

Date.	Registered No.	Provisional Name	Locality and Remarks
22-3-16	405	Consolidated Shelly and Sandy Limestone (Dwárka)	Surface of 22 feet well-shaft. 500 yards ESE of Cháya.
22-3-16	406	Potter's-Clay. Marginal Alluvium of Salt-swamp	200 yards SSW. of Rabári Nes, ESE. of Cháya.
22-3-16	407	Potter's-Clay. Marly Alluvium of Balvi Talav.	SW. end of Báwá-ká-Mát $\frac{3}{4}$ mile SE. of Cháya
22-3-16	408	Shelly and Coralliferous Dwárka-beds Limestone.	$\frac{1}{4}$ mile S. of Cháya. Base of quarried Hill-ridge.
22-3-16	409	Sub-recent Consolidated Shell-sand. Raised Dune	$1\frac{1}{4}$ miles S. of Cháya. Old Pit called Mithi Khán.
22-3-16	410	Consolidated Shell-sand Raised Beach.	200 yards SW. of 409. Used for walls round Ráj Máhál
22-3-16	411	Natural Chunam	50 yards SW of 410

On the 24th instant, the specimens collected were carefully packed, tied up securely in gunny-bags and sent by cart to headquarters in Porbandar together with a parcel of prepared chips and slices of stone to the mechanic for preliminary manipulation on the lapidary-bench. Arrangements were also completed on the day following for the transference of the camp to the sea-side village of Adodar, (pronounced Aorda), and tents were struck at Cháya at dawn of day on the 26th instant.

With a view to covering as much untraversed ground as possible, a roundabout route was taken in journeying from Cháya to Adodar as follows :—The ENE. cart-track was followed in the direction of Ránghá-wáo and necessarily entailed the crossing of that branch of the vast Salt Marsh, which leads towards and encircles the eastern side of Porbandar City as The Creek. On reaching the east side of this alluvial tongue, about one mile NE. by ENE. of Cháya, a portion of the depression was found to have been dammed off and deepened to form a talav or freshwater reservoir, where the obscured Dwárka, flaggy limestone was found covered by from 1 to 2 feet of much cancellated and shaly miliolite limestone, altered almost beyond recognition into a dense, grey substance by alternate sunbaking and monsoon conditions;—the shaly aspect of the stone, being apparently due to the weathering and subsequent hardening of the laminæ of the structure. It will be interesting to observe the precise nature of the changes that have taken place in specimens secured for future microscopic examination.

Proceeding along the cart-track eastward, to the village of Rángháwáo, the surface of the ground was found to be deeply composed of more or less false-bedded flagstones, rendering the roadways exceedingly rough and rutty; and samples of this stone dipping at various angles superficially by reason of their oblique lamination, immediately proclaimed the material to be a shelly and coralliferous, arenaceous limestone, clearly continuous with the surface Dwárka Group beds of Cháya.

From Rángháwáo the roadway nearly due south to Adodar was followed, for about a mile, well into the north-westward branch of the Great Salt-Marsh. A sample of the tolerably deep deposits at this part showed it to be composed of a fine, grey alluvium plentifully mixed with sand and the comminuted shells of both estuarine and littoral marine *Mollusca*:—*Cardium, Tellina, Ostrea, etc.* The course was then altered eastward, and followed along a beaten track at the edge of the salt marsh for about a couple of miles to a spot marked on the G. T. S. 1 inch to 1 mile map, as Khokhri Parab. Here there were found two empty stone sheds with a small well-shaft by the side of one of them, erected at the expense of a Bombay merchant, in memory of his daughter, to afford refreshment for thirsty travellers. The well, which is about 10 feet deep, shows the ground to be composed of thin, shelly flagstones of the Dwárka Group.

At Khokhri Parab, a strip of stony ground about 1½ miles by about ½ mile at its broadest part, remains uncovered by alluvium; and by crossing over this patch in a SSW. direction, a temporary pathway was found leading to the SW. end of an eminence, 56 feet above the level of the sea, called Chirora-ka-Tobra, which, when the marsh is flooded forms a small, narrow islet. The dark grey alluvium of the salt marsh, barely covering the substratum of Dwárka flagstones, surrounds this eminence, which, from base to summit is built up, so to speak, of false-bedded arenaceous limestone, very closely laminated, and in such an advanced stage of decay at all exposed parts, that it was difficult to secure even a small sample sufficiently unweathered to hold together intact, when detached from the main mass.

Scrubby, ill-nourished, stunted grass was found struggling for an existence on the alluvium, between Chirora-ka-Tobra and the permanently dry rock-land 3½ furlongs to the SW., and a further drive of 1¼ miles in the same direction brought the journey to an end at Adodar. It may be noted that the entire strip of countryside intervening between Adodar and the western margins of the Great Salt Marsh is constituted by a considerable thickness, frequently shown by shafts of wells to

exceed twenty feet, of fossiliferous flagstones and conglomeratic, rubbly rocks, belonging presumably to the lower beds of the Dwárka Group of Tertiary strata.

Specimens collected during the abovenoted journey, and added to the Registered List, are as follows :—

Date.	Regis-tered No	Provisional Name	Locality and Remarks
26–3–16	412	Altered Miliolite-limestone. Indurated and Pseudoshaly	1 to 2 feet thick Talav bank. 1 mile NE. by ENE. of Chaya
26–3–16	413	Shelly and Coralliferous Flagstone False-bedded	100 yards WNW. of Rángháwáo Stone on which the village stands
26–3–16	414	Sandy and Shelly Alluvium of Dry Bed of Salt Marsh	¾ mile SSE. of Rángháwáo
26–3–16	415	Arenaceous Limestone. Much decayed. False-bedded and Finely Laminated	SW base of Chirora-ka-Tobra 56 feet above sea-level 1¾ miles NE. of Adodar.

Camp-Station XVI.—Adodar.

NE. End of the Town.

TENTS WERE PITCHED in a small hedged field bordering the NE. end of the town on the 26th instant ; but it was late in the evening before everything could be got into good working order. While the tents were being got ready, however, the opportunity was taken to examine the surroundings of the town and its adjacent sea-shore, accompanied by the Patel and a bullock-cart.

A cutting of the ground adjoining the camp, showed that the town of Adodar is built upon a 3 to 6 feet substratum of rubbly, russet-coloured, concretionary limestone of dense texture, which immediately overlies beds of Dwárka flagstones ; while the true nature of the latter as richly fossiliferous shelly and coral-bearing limestones, thickly flaggy above, then distinctly shaly, and more or less conglomeratic below, is demonstrated by well-shaft exposures about 200 yards to the NE. of the town.

Asked if there were any quarries in the neighbourhood, the Patel led the way to an eminence ½ mile WNW. of the town and about 500 yards distant from the sea-shore, where a deposit of inferior grey-brown

limestone of but little commercial value had been largely quarried to a maximum depth of 20 feet, up to about eight years ago. This stone closely resembles the inferior qualities of Cháya-limestone, and like that formation, rests upon a substratum of Dwárka fossiliferous flagstones, and is evidently a consolidated blown-sand.

From the quarry site, which is not a very extensive one, a roundabout detour was made to the sea-shore $\frac{5}{8}$ mile WSW. of Adodar, so as to be in time to examine the breakers exposed at low-tide mark. Samples of these were taken and found to consist of very thick beds of consolidated shelly and sandy limestone, in all respects identical with the stone forming similarly situated breakers all the way along the shore to Porbandar City and beyond

As there was ample time for further investigation, it was proposed to ascend the hilly slopes inland to the top of a high-ridge called Sálák Tobra, the summit of which, 96 feet above the sea-level, stands at a distance of $\frac{7}{8}$ mile NW. by WNW. of Adodar. The Patel of the town first of all said that there was no cart track that way, and then protested that as there was no utilisable stone of any kind in the direction indicated, it would be only waste of time and tiring into the bargain to go there. He was however, given to understand that the ground *had* to be examined and reported upon at all hazards ; and it was not until then, that he suddenly remembered that there was an excellent cart-road skirting the base of the ridge, and an easy pass between the ridge-hillocks leading directly back to Adodar. The cart to carry samples was accordingly sent along the roadway with instructions to halt on the E. side of Sálák Tobra, while the surveying party climbed up the W. slope of that hillock to its summit, 96 feet above datum. It was discovered that the base of the hillock on its seaward side, was subjected to the periodic flooding during the monsoon of a channel running practically parallel with the shore, but inland with reference to the long, low ridge of sand dunes bordering the beach. The swirling of the turbulent waters of this temporary river at its E. margin, has been effectual in baring the thick flagstones there situated, and of rolling fragments thereof into ovoid and discoid pebbles of about 6 inches in length, composed of both fine and coarsely textured shelly and sandy limestones of the Dwárka Group, in continuity with the beds registered as No. 410, from which the so-called " black-stone " was extracted for building the walls surrounding the Ráj Máhál.

On ascending the western slope of Sálák Tobra, the Dwárka Group flagstones abovenoted were found to constitute the entire body of the

hillock and adjoining ridge right up to the very summit ; and the deposits were observed to be markedly false-bedded. But, upon descending the eastern slope, it was, to say the least, surprising to find a goodly deposit of compact, white, and very finely-textured limestone, bearing signs of having been sparingly quarried many years ago and of also having been quite recently drawn upon on a very limited scale. The Patel, upon being interrogated, protested that he was entirely ignorant of even the existence of such stone in his immediate neighbourhood ! The stone, of which there appears to be but a moderate development on the eastward slopes of the ridge, at first sight appears to be equal, if not superior, to the best grade and quality of Ádatiána Heights " Porbandar-Stone "; but, upon being tested, was found to be very much inferior in points of strength and cohesion of its units or clastic particles ;—rendering it useless for ornamental or carved work. Nevertheless, it is superior to the somewhat similarly constituted Cháya-limestone and therefore worth while being prospected, especially by reason of the sites being easily accessible and within reach of a level roadway barely over five miles distant from the centre of the City of Porbandar.

On the morning of the 28th instant a traverse along the sea-coast from Adodar *viá* Tunkra to Gosa, and back to the camp by way of inland routes was projected and accomplished as follows :—The SE. by SSE. sea-board roadway gradually receding from the long, low ridge of protecting sand-dunes, was taken in the direction of Tunkra, and occasional halts were called for the purpose of examining the sea-coast on the west and the gradually diminishing ridge of hillocks on the east side of the roadway, without any noteworthy results other than those that have already been recorded with reference to the general geological structure of the coastal regions to the immediate W. and NW. of Adodar.

In this way the countryside was traversed for fully three miles, when a small excavation by the roadside in front of an isolated cottage and $\frac{3}{8}$ mile distant from the sea-shore, revealed the presence of a few feet in thickness of sub-recent consolidated shell-sand ;—evidently the basal portion of a raised sand dune, overlying the shelly and sandy flagstones of the Dwárka Group of beds.

Half-a-mile farther SE., or about $1\frac{1}{4}$ miles NW. of Tunkra, a bar of sand occludes the mouth of a very wide creek, which, at this time of the year constitutes a kind of natural salt-pan, and the narrowed NW. termination of this pool of dammed-in brine, is spanned by a strong causeway, on the E. side of which several labourers were gathering evaporated salt.

The stony exposed surface at the SSE. end of the causeway, was found to be constituted by Dwárka Group flagstones, the laminæ of which were weathered and worn down in such a way as to present a shaly aspect ; and upon the surface of these slabs, in patches every here and there, there were found large numbers of recent shells,—*Cardium, Conus, Venus, Turritella, Ostrea, etc.,*—so firmly cemented to the substratum as to appear to be part and parcel of the same.

On approaching Tunkra, a well-shaft, about 500 yards NNW. of the village, exhibited about 4 feet of a rubbly, much cancellated, sandy limestone overlying about 8 feet of apparently compact, solid shelly and sandy Dwárka Group stone ; while another well-shaft at the NW. end of the village, showed an unbroken depth of 12 feet of the last named stone without any tendency to become flaggy or false-bedded.

Tunkra village stands on a foundation of the aforenoted shelly and sandy Dwárka Group limestone, which instead of being flaggy as heretofore recorded, is here locally developed into solid imperceptibly laminated beds of considerable thickness, capable of being extracted and cut into building-blocks of large dimensions ; and it is but reasonable to expect that the stone if available in sufficient quantities, would not only be far stronger than the miliolite, but able to withstand seaside and salt-spray weathering more effectually than the latter.

Passing to the seaward side of Tunkra, about 100 yards WSW. of the village, there is an elongated pit-quarry which shows a very fine development of the Dwárka consolidated shell-sand, overlaid on its westward side by about three feet of a coarse, soft and much cancellated shell-sand which rapidly diminishes to nil before reaching the village boundaries The partially decayed solid stone, which comes to the surface close by and beneath the village, it is stated, yields a very strong lime when kilned ; but the stone when quarried from the base of the rubbly rock, has been sparingly extracted in blocks of large size and used for the building of dwelling houses, although nothing has hitherto been done towards making the material known.

Between Tunkra and the sea, a wide slope of partially cultivated ground, from 300 to 400 yards broad, extends to the edge of the long, low ridge of sand dunes, which in their turn incline to pass insensibly into a beach, 200 yards wide, of fine sand, before the breakers at low-water mark appears. The latter, consist of thick beds, more or less flaggy of a coarse variety of the same stone upon which Tunkra stands. This stone at parts is riddled with the borings of *Lithodomus* and *Pholas*.

The coast line and its immediate inland areas from Tunkra to Gosa,

a distance of about 2½ miles in a SE. by SSE. direction is essentially similar in all details to that which has just been described. At Gosa itself, however, which lies a little over ½ mile inland, a tolerably deep deposit of greyish-brown, inferior consolidated blown-sand presented itself, and has been quarried to a depth of from 6 to 8 feet, for State use, on the S. side of the village.

From Gosa with its crust of coarse sandy-limestone overlying rubbly fossiliferous limestone of the Dwárka Group, the NE. inland roadway was followed right up to the alluvial plain-bottom of the Great Salt Marsh. Bearings were taken at a place 2 miles NNE. of Tunkra to indicate a wide area of alluvium holding myriads of the dead shells of a small *Cerithium*; while at another place, 2 miles NE. of Tunkra, the alluvium was literally white, for several hundreds of yards in every direction, with the large shells of littoral-marine molluscs;—principally *Cardium* and *Conus* in a semi-fossilised condition, many of these shells were found so firmly imbedded in rubbly lumps of Dwárka Group limestone, as to convey the impression of being part and parcel of the latter; and, bearing in mind the famous Huttonian doctrine that 'the present is the key to the past,' a good lesson might be learned from this occurrence; *viz.*, that conclusions as to the horizons of many of the older stratified sedimentary rocks ought not to be too hastily formed and recorded.

On the 30th instant tents were struck at Adodar at 7-15 a.m. and the camp was transferred to the inland village of Mokal, right across an 8-mile stretch of principally salt-marsh alluvium in an ENE. direction. Nothing noteworthy could be recorded on this monotonous journey save the heavy and tiresome drag through deep and yielding, soft grey clay, just barely redeemed from becoming a cloggy mud.

At a distance of about 2 miles W. by WSW. of Mokal, the aspect of the ground acquired a perceptible change; partly due to a slight elevation, and partly from the circumstance that the earth was no longer laden with salt. This was testified to by the presence in the alluvium still of a deep-grey colour, of numerous freshwater and land shells:—principally *Planorbis*, *Bulimus*, *Cyclas*, *Paludina*, and a few small *Helices*,—here named in the order of their abundance.

As the carts with the tents and equipments were not expected to arrive at Mokal for an hour or two later, the journey was continued to Bápodar and back; but it was everywhere noticed that the soil of the countryside,—very deeply developed,—consists mainly of admixtures of saliniferous alluvium and highly calcareous detrital washings from the northern uplands, bearing a burden of more or less miliolite drift. Most

of the well-shafts showed the water-level at but a few, (10 to 15) feet from the surface ; but the water, with rare exceptions, turned out to be brackish, and, in some cases quite putrid ;—presumably through underground stagnation.

From the unusual depth and incoherent nature of the soil, all the local well-shafts from Mokal to Bápodar are necessarily lined with stone but, fortunately, on the return journey from Bápodar by a different route, a newly dug well-shaft was encountered, $\frac{3}{4}$ mile W. by WSW. from that village, which furnished an unerring clue to the geological structure of the countryside. The well-shaft in question showed the underground water-level at a depth of 18 feet from the surface ; but the bottom of the shaft was found to be 4 feet deeper. The first 18 feet was sunk through a very highly calcareous soil, followed by a foot or so of concretionary lime invading the thoroughly decomposed surface of a bed of amygdaloidal lava, altered almost beyond recognition, but passing downward into fully three feet of somewhat less decayed but unmistakable bedded-lava with veins of zeolite, and well preserved amygdales.

It is thus clear, that the Tertiary strata of the coastal regions thin down to vanishing point at or in the vicinity of Mokal, and that detrital soil, chiefly derived from the Pleistocene miliolite deposits thereafter rests directly upon the bedded-lavas of the Deccan-Trap.

Additions to the State Geological Collection up to the end of March, 1916, are :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
27-3-16	416	Rubbly. Russet. Concretionary Limestone	NE. end of Adodar. Stone on which the Town stands.
27-3-16	417	Shelly and Coralliferous Conglomerate.	Underlying 416. Top of well-shaft 200 yards NE. of Adodar.
27-3-16	418	Shaly, Limy Flagstone.	Interbedded with 417.
27-3-16	419	Blown-sand Limestone. Grey-brown, soft. Building-blocks.	Large disused Quarry, $\frac{1}{2}$ mile WNW. of Adodar.
27-3-16	420	Consolidated Shell-sand. Dwárka Group. Large Flagstones.	Breakers at Low-tide Mark. $\frac{5}{8}$ mile WSW. of Adodar.
27-3-16	421	Discoid-pebble of Consolidated Shell-sand Limestone.	Inland, 300 yds. from Shore. $\frac{3}{4}$ mile W by WNW. of Adodar.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
27-3-16	422	Consolidated Shell-sand Limestone. False-bedded.	Summit, 96 feet above Sea-level Sálák Tobra. NW. by WNW. of Adodar.
27-3-16	423	Limestone, Finely textured, white, but not Carvable Big Blocks.	Disused Quarry-site. East slope of Sálák Tobra, $\frac{7}{8}$ mile NW. of Adodar.
28-3-16	424	Sub-recent Consolidated Sand-dune Sand	Small pit excavation. 3 miles SE. by SSE. of Adodar.
28-3-16	425	Evaporated Salt of Occluded Creek.	E side of SSE. end of Causeway. $1\frac{3}{8}$ miles NW. of Tunkra.
28-3-16	426	Shaly, Indurated Flagstone Dwárka Group Beds.	SSE. end of Causeway, $1\frac{3}{8}$ miles NW. of Tunkra.
28-3-16	427	Recent Semi-fossilised Shells, cemented to 426.	Same site as 426. In irregular Patches.
28-3-16	428	Consolidated Shell-sand. Soft and Much Cancellated.	Small Quarry. 3 feet thick surface stone. 100 yards WSW. of Tunkra.
28-3-16	429	Consolidated Shell-sand. Thick, Solid, Large Blocks.	Underlying 428 for fully 12 feet Stone on which Tunkra stands.
28-3-16	430	Sea-beach Sand. 200 yds. wide ..	$\frac{3}{8}$ mile SW. of Tunkra.
28-3-16	431	Consolidated Shell-sand	Low-tide Breakers. Same site as 430.
28-3-16	432	Coarsely-porous, Grey-brown Blown sand Limestone.	S. side of Gosa. 6 to 8 feet deep. Quarry for State use only.
28-3-16	433	Alluvium of Salt-marsh. With myriads of *Cerithium* shells.	2 miles NNE. of Tunkra Spread over Local Areas.
28-3-16	434	Consolidated Shell-sand with adherent Sub-recent Shells;—mainly *Cardium* and *Conus*.	2 miles NE. of Tunkra. Covering wide areas of the Great Salt-marsh.
30-3-16	435	Alluvium bordering Salt-marsh. Containing Freshwater and Land Shells.	2 miles W. by WSW. of Mokal.
30-3-16	436	Concretionary-lime, Invading Decayed Amygdaloidal Lava.	At depth of 20 feet Well-shaft $\frac{3}{4}$ mile W. by WSW. of Bápodar.
30-3-16	437	Decayed Amygdaloidal Lava ..	Immediately underlying 436.

DIGEST OF DIARY.

April, 1916.

Camp-Station XVII.—Mokal.

SSE. End of the Village.

AN EXCELLENT SITE having been found adjoining, but not too close to the dwellings at the SSE. end of the village, the camp was established and got into satisfactory order on the evening of 30th March, 1916; and, upon the following day, all monthly accounts and other outstanding items having been prepared, the Clerk of the Department was sent to the Hazur Office to adjust matters; while the writer was kept busy in camp drawing up the concluding pages of the last monthly report, which was duly completed on the 2nd instant.

On the morning of the 1st of the month, the structure of the ground around and about the village was examined, well-shafts were inspected, and the neighbouring reservoirs visited with the following results:—

Mokal village is situated nearly eight miles SSE. of the southern base of the Barda group of hills on the north-eastern margins of the Great Salt Marsh of the State; and is practically hemmed in on the NW. and S. by portions of saliniferous alluvium. As a direct result of this peculiar environment, the ground for a radius of fully one mile surrounding the village consists of a very deep layer of soil, intensely calcareous and volcanic towards the N., NE., E. and SE., but mainly composed of salt-marsh alluvium indued with sand and lime from the immediately underlying Post-pliocene Dwárka Group beds

The water-supply problem is therefore a difficult one to solve; but the difficulty has to some small measure been met by the conservation of the surface drainage in dammed up reservoirs on the NE. and SSW. sides and farther (about ½ mile) W. and SW. by WSW. of the village. When these artificial ponds go dry, as they do at this time of the year, the villagers are obliged to resort to their wells; and these unfortunately, are either slightly brackish or quite foul and unfit for domestic purposes. Only at one spot, immediately above the gravelly subsoil of the NE. *talav* or reservoir of the village, has the surface drainage water been found to remain passably potable;—doubtless by reason of a modicum of natural aeration; for, not many yards distant, where there is a large and tolerably deep well-shaft, the surface-water percolates down to the

impervious clay below, and there, from the presence of a sufficient quantity of probably introduced as well as inherent organic matter, putrefaction sooner or later ensues. At the present time the well-water, teeming with myriads of *Bacteria, Paramœcia,* and other noisome germs s disgustingly fœtid; but, in spite of that, a few women and children were observed washing their clothes and persons therein;—*de gustibus non disputandum.*

From the deep character of the soil, which is said to be very fertile at places, all the well-shafts have to be securely lined with stone, right down to and even below the water-level; so that the nature of the subsoil and underlying stone is veiled, excepting where new well-shafts are being sunk, as in the instance already recorded of the excavation ¾ mile NW. of the neighbouring village of Bápodar.

Accompanied by the village potter, a visit was paid on the 1st instant to the sites from which clay is locally obtained for tile and earthenware making. The scanty layer of alluvium annually deposited on the bottom of the *talav* on the SSW. side of the village, dries into a hard, dark-grey coherent mass, which when kneaded with water and the ashes of horse-droppings, is "thrown" into rough tapering short tubes, cut lengthwise, and "fired" into good, strong native roofing tiles.

For the fashioning of chatties and other vessels for domestic use, a less gritty and more tenacious clay, full of the fibrous roots of dead grasses is somewhat similarly treated;—the material being dug out from the first few superficial inches of the alluvium from a pond, ½ mile SW. by WSW. of Mokal; and it was confidentially told, that the red chatties were burnt under intense heat at the bottom, and the black earthen pots, at a lower temperature towards the top of each temporary kiln.

Around the abovenoted *talav*, the flat countryside, covered with a kind of coarse gravel, is thickly overgrown with big bushes of the thorny and leafless Edible Caper, *Capparis aphylla,* now conspicuous from afar, by their dense clusters of vermilion blooms. The buds and young fruit of this plant, when pickled in brine, are much esteemed by native epicures, who also relish the bright cherry-red, ripe fruit; which, to strangers, have a sweetish but sickly flavour.

On the 3rd instant an excursion was taken northward and eastward to cover hitherto untraversed ground as follows:—The N. by NNW. road leading to Ránáwáo was taken over a flat alluvial plain for fully two miles before anything noteworthy could be observed. A halt was then called to examine a slight eminence thickly strewed with broken stone,—principally fragments of miliolite-base drift,—where also a

small well-shaft was found. This exposure proved to be essentially similar to the one already referred to as occurring $\frac{3}{4}$ mile NW. of Bápodar, by exhibiting about 11 feet of superficial calcareous soil, lying upon nearly one foot of concretionary lime which was found impregnating the underlying bed of much decomposed amygdaloidal lava. The underground water-level stood at a depth of 18 feet from the surface.

Proceeding thereafter to a distance of $3\frac{3}{4}$ miles N. by NNW. of Mokal, the surface soil gradually diminished, *en route*, to nil, and a wide roadside, dry nála-channel, showed the bedded-lava at the surface in a curiously characteristic way. The compact bedded-lava, eroded by the stream, showed a number of clearly-mapped vertical columns transversely shorn across to display their polygonal outlines ; and these were emphasised by the deposition in the joint-fissures of solid masses of concretionary lime. There can be no doubt that this exposure must at one time have been covered with a highly calcareous deposit of some sort, and that the lime therefrom must have been dissolved by carbonated water and carried down to be redeposited in a concretionary, amorphous form between the joint-fissures of the bedded-lava below ;—much in the same way as it is now reacting at the base of the well-shaft noted above.

About one mile farther in a NW. direction or one mile SE. of Ránáwáo, the ground rapidly rises, and becomes increasingly covered with deposits of the miliolite-base ; but upon turning ENE. to meet the main highway from Ránáwáo to Kandorna about $1\frac{1}{2}$ miles E. by ESE. of Ránáwáo, the miliolite again becomes deficient, and the N. side of the so-called made-road is superficially excavated for some distance for an indurated shelly limestone of a ruddy-buff colour, which is not only perforated and constituted by inch-thick laminæ, loosely held together, but is markedly false-bedded. This deposit which evidently belongs to the upper Post-pliocene portion of the Dwárka Group of beds, is largely used for metalling the adjoining high road ; and, unless tarred and dressed with granophyre chips, to take the surface wear and tear, cannot be expected to last much longer than a single season, and must therefore be regarded as wasteful.

A rapid drive along formerly traversed ground ESE. to Wadwála, a distance of $4\frac{1}{4}$ miles, could not very well be avoided ; but, during that drive, from frequent peeps into wayside well-shafts, it was observed, that while the underground water-level of good potable water in the neighbourhood of Ránáwáo, varied from 5 to 10 feet from the surface, that of Wadwála had subsided to a depth of no less than 32 feet.

From the SW. end of Wadwála, a somewhat straggling cart-track across country, frequently encroached upon by fields under cultivation was followed for a distance of 4½ miles SW. to the camp at Mokal. The surface of the land at Wadwála bearing an appreciably deep deposit of denuded and decayed miliolite-base stone, gradually assumed a volcanic character, thickly and then thinly strewed with miliolite drift, until about 1½ miles NE. of Mokal the decayed subsoil of amygdaloidal lava appeared at the surface, only to be speedily obscured farther SW. by increasingly deep, deposits of highly calcareous detrital soil, tailing down westwardly to be absorbed by the alluvium of the Great Salt Marsh.

Tents were struck at 6 a.m., and the camp was transferred to Navibandar on the estuary of the river Bhádar,—the largest and longest watercourse in the Province of Káthiáwár. The SW. cart-road from Mokal runs over an undulating gravel-strewed alluvial plain, for about ¾ mile before entering upon the dry, flat bottom of the Great Salt Marsh, which is more or less deeply covered with a dark-grey, sterile alluvium, and continues over an unvarying stretch of similar ground for fully 3½ miles ; to a barely perceptible elevation, called Janga Bet, where the alluvium is strewed with some coarse sand, gravel and comminuted marine shells. From Janga Bet the temporary track swerves S. by SSW. to the village of Gosa, the outlying geological structure of which has already been noted, as being characterised by a tolerably deep deposit of inferior, soft, greyish-brown limestone.

These deposits of inferior stone are quarried for State local use in the immediate neighbourhoods of Gosa and the small village of Nawagám or Rájpurá, ¾ mile farther SE. The small pit-quarry on the brow of the hillock, about 100 yards NW. of Nawagám shows a soft, light-brown perforated but fairly compact stone, which gradually merges, at a depth of about 12 feet into a very porous shelly stratum ; and ordinary building-blocks, are hewn out of this deposit down to about 15 feet, when operations are stopped by the underground water level from the surface of the less pervious hard, shelly and sandy limestone of the Dwárka Group.

From the abovenoted site, a southward course was taken for the purpose of observing the sea-shore between Gosa and Navibandar ; and it was found, that with but unimportant variations, chiefly with reference to the proportionate breadths of beach, blown sand-dunes, and inlying outcrops of Dwárka Group shelly and sandy limestones, which also reappear as low-tide mark breakers, the structure of the shore-lands is wonderfully uniform, until interrupted by the narrow and shallow

spit-bound mouth of the river Bhádar, ¾ mile NW. by WNW. of the town of Navibandar.

Returning from the shore to the main-road 2 miles NW. by NNW. of Navibandar, a bold exposure of much cancellated, hard and splintery Dwárka Group limestone, emerges by the roadside from its covering of blown sand ; but the latter does not at this part, show signs of consolidating upon the former. Farther SE., however, in the neighbourhood of Sikása, a well-shaft, situated about 300 yards N. by NNE. of that village, disclosed the Dwárka limestone in flaggy beds for about 5 feet in total thickness, overlaid by some 3 feet of gravelly and shelly conglomerate very heavily impregnated with lime. A rapid drive over ground of this character in a SW. direction for ¾ mile, brought the party to the N. bank of the Bhádar Creek where it bends north-westward to its spit-bound outlet to the sea. Here, a ferry-boat remains in readiness to convey passengers and vehicles southward for about 500 yards across the Creek to the landing-stage of Navibandar.

Specimens collected, registered and added to the State Geological Collection are :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
1-4-16	438	Gritty, Limy Conglomerate. Subsoil. Probably Post-Gáj.	Underlying Aluvium of Talav. NE. end of Mokal.
1-4-16	439	Potter's-clay for Native Tiles, and Coarse Earthenware.	Alluvium of Talav SSW. side of Mokal.
1-4-16	440	Potter's-clay for Chatties and Superior Earthenware.	Alluvium of Talav, ½ mile SW. by WSW. of Mokal.
2-4-16	441	Compact Bedded-lava Reticularly jointed.	Dry bed of Roadside Nála. 3¼ miles NNW. by N. of Mokal.
3-4-16	442	Concretionary Lime. filling Vertical joints in 441.	Same site as 441.
3-4-16	443	Miliolite-base Conglomerate. 6 to 12 inches on Surface.	One mile SE. of Ránáwáo.
3-4-16	444	Shelly and Sandy Limestone Ruddy and False-bedded. Dwárka ?	1½ miles E. by ESE. of Ránáwáo. Roadside. Used for Metalling.
3-4-16	445	Decayed Amygdaloidal Lava ..	Surface. 1½ miles NE. of Mokal.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
5-4-16	446	Blown-alluvium of the Great Salt Marsh.	Janga Bet. 3½ miles SW. of Mokal.
5-4-16	447	Light-brown. Soft. Limestone ..	Surface. Small Quarry. 100 yards. N. by NNW. of Nawagám.
5-4-16	448	Shelly Limestone.	Underlying 447 at depth of 12 feet.
5-4-16	449	Shelly and Sandy Limestone Post-Pliocene Dwárka Beds.	Breakers at Low-tide. Shore. ⅛ miles SSE of Gosa.
5-4-16	450	Post-Pliocene Limestone. ..	2 miles N. by NNW. of Navibandar.
5-4-16	451	Limy. Gravelly and Shelly Conglomeratic Subsoil. 3 feet thick at Surface.	Top of Large Well-shaft 300 yards or so. N. by NNE. of the village of Sikása.
5-4-16	452	Compact. slightly Cancellated Flaggy Limestone of the Dwárka Group of Beds.	Immediately underlying 451, 5 feet in total thickness, and overlying Rubbly Beds.

Camp-Station XVIII.—Navibandar.

Traveller's Bungalow. About 200 yards SE. of the Town.

ON ARRIVAL at the bend of the N. bank of the estuary of the river Bhádar, opposite to Navibandar Town, considerable delays were occasioned by crossing over the Creek of about 3 furlongs wide in a flat-bottomed ferry-boat propelled by poles over a 12-feet deep channel; so that it was very late in the evening of the 5th instant, before working arrangements could be completed at the Traveller's Bungalow;—situated as noted above. Time, however, was afforded for a few local observations, while the camp equipments were being transferred from the ferry landing-stage to the bungalow, as follows:—

The mouth of the great Bhádar river opens into its wide estuarine Creek, abounding in many kinds of edible fish, about 1¼ miles ENE. of Navibandar, where the channel is spanned by a substantial bridge with locks and flood-gates. Approaching the N. end of the ferry, there is a considerable area of overflows, usually smothered with mud, where countless small mud-skippers, (*Periophthalmus koelreuteri*), beloved of

Parsi *gourmets*, may be watched disporting, in, out and over the slimy sludge with lightning rapidity. Some of the native boatmen on the river banks confessed that they were rarely good to eat.

Deepening at the ferry and then shallowing down seaward, the creek is deflected, from its E. to W. course, to the NW.,—by a sandy bar,—to terminate in a backwater, a trifle over 2 miles to the NW. of Navibandar; but, before reaching to that distance, breaks through by a narrow sand-silted outlet, into the open sea, some $\frac{7}{8}$ miles NW. of Navibandar. The sandy bar, or spit, is not by any means an insubstantial, shifting entity; but can boast of a solid foundation of hard, consolidated shelly and sandy limestone, which forms big breakers seaward at low-tide mark, and is re-exposed inland beyond the limits of the æolian dunes.

On the morning of the 6th instant, further local observations were made, during a traverse coastwise, on foot. Boldly situated at the inland edge of the sand-dunes facing the open sea at a distance of scarcely over 150 yards from low-tide mark, the Traveller's Bungalow is invested by an appreciable quantity of blown-sand, which is fortunately retained *in situ* as follows:—From 50 up to 300 feet SW., or seaward, the sand is held firmly together by closely growing bunches of sedges, and the ground slopes gently downward to a line of the still more strongly binding creeper *Ipomœa biloba*, with its powerful network of underground stems, which keeps the shifting particles together in a continuous level ridge. So soon as this bindweed ceases to grow, the sand drops down perceptibly, forming a kind of small pseudoscarp; and, after a a short level space, by reason of the disposition of the underlying beds of rock, the beach slopes down abruptly to low-tide mark. Farther NW. and also about $\frac{1}{2}$ mile SE., the beach inclines gently to terminate at low-tide mark, in a line of thick flagstone breakers, belonging to the Dwárka Group of beds; and this, with but unimportant variations, characterises the coast-line all the way from Porbandar to Navibandar.

Evidence of the elevation of the land during Sub-recent and Recent times is admirably afforded on the W. side of Navibandar, where a steep 10 to 12 feet scarp, of false-bedded, sub-aerially consolidated, soft shell-sand, forming part of the foundations of the town, is conspicuously exposed; and can be directly traced in continuity with the lower portion of the existing seaward dunes. There can be no doubt that this stone represents the wreck of a former dune, which once bordered the beach, but has since acquired its present inland position, by the raising of that beach.

Continuing north-westward along the sandy-bar ½ mile NW. by WNW. of Navibandar and near to the partially silted mouth of the Bhádar Creek, the shore-line at low-water mark, as usual, exhibited its share of breakers of thick flagstones. On the spit itself the latter were, of course, deeply obscured by sand; but on the SW. bank of the creek they were re-exposed in fine development of sound and compact very thick slabs of stone which would be well worth extracting for building purposes if it were not for its unfavourable situation. The same stone, however, all along the coastal region from Tunkra to Navibandar and doubtless far beyond, obtains in great abundance; but like all other sedimentary deposits varies in texture, structure, and *ergo* utility, both horizontally and vertically; so that profitable quarrying sites,—save those that are superficially apparent or accidentally disclosed by well-shafts,—can only be indicated with certitude by systematic prospecting with a calyx or other boring drill.

On the 7th instant a careful traverse along the coast, as well as inland, was made SE., as far as to Ratia Nes; and thereafter across the wide alluvial and agricultural plains to the village of Garej, and back by way of the Bhádar Bridge and Sikása,—with the following results:— On the upper or inland road to Rátia a brief pause was made to view the ruins of an old stone-stepped sacred tank on the SW. side of the road ⅞ mile SE. of Navibandar, where the ground on the NE. rises into a low continuous ridge of rough surfaced flaggy limestone of the Dwárka Group of beds, which is intermittently incrusted with thin deposits of coarse and much decayed limestone bearing a strong miliolitic facies.

It may here be noted that it is often very difficult to distinguish, by the naked eye alone, between deposits of miliolite and the frequently decayed, finer-grained limestones of the underlying Dwárka Group; so that occasional errors may creep in, in spite of every care, while giving provisional names to these rocks. Such errors, however, can of course be to a measure rectified as soon as specimens are examined in the laboratory.

Proceeding Ratiawards, the elongated, comparatively narrow ridge gradually rises to an elevation of 39 feet above the sea-level, and is then depressed but continuous, and traversed by the roadway all along to Ratia. Samples of its stone were taken at 2 miles SE. of Navibandar, as fairly typical and were found to consist of a compact shelly and sandy limestone, false-bedded, prone to vary both horizontally and vertically, and to yield large flagstones, frequently sound and solid, of from 6 inches to over 2 feet in thickness. The ridge runs in a sub-

parallel direction about ½ mile inland from the sea-shore, and is thickly 'clothed' with clumps of very robust *Euphorbia nereifolia*, now in full bloom. The bland, inspissated latex of this plant, it appears, was sent to Europe with a view to extracting rubber therefrom, but the reports were so discouraging that no further effort was made, since 1891, to utilise the product. In spite of this, the writer sent samples to London, and received a very favourable report from an expert analyst, who stated that the substance was so rich in gutta-percha and other utilisable by-products that it would be well worth while sending test consignments to him, with the assurance that they would find a ready and probably profitable market.

All the way along from Rátia to Rátia Nes, and beyond, the ridge of Euphorbia-clad, flaggy limestone continues unabated. Well-shafts by the roadside and towards the sea-board were frequently inspected;—notably 2½ miles SE. of Navibandar,—and found to show a very considerable depth of sound and solid but more or less cancellated limestone in many varieties of texture and exceedingly hard; from which enormous quantities of useful, salt-spray resisting, building-stone in blocks of large size and thickness could be readily extracted; but, as uniformity of, quality cannot be guaranteed, it is very doubtful whether prices could be realised to cover even cartage expenses, except for short distances.

Some of these Dwarka Beds of comminuted shells and grains of sand, compacted firmly together, are of such fine texture, as to yield polishable blocks of a distinctly ornamental character; but, when found and followed, almost invariably degenerate within a few feet into fissile flagstones or very coarse porous material. Other beds of fine and apparently azoic composition, may yield a few big blocks free from rifts and flaws, to suddenly pass into heterogeneous masses full of ungainly perforations; but, nevertheless tough and strong enough for building-blocks of inferior grades and qualities; so that, on the whole, the vast development of material, undoubtedly present, could scarcely be turned to profitable account, except by systematic prospecting with boring appliances; or, by desultory quarrying, to meet local demands. It may confidently be anticipated that these remarks will be found substantially correct with reference to the entire sea-board and its immediate inland areas, right down southward to Mádhavpur and beyond.

At Rátia Nes, which is situated fully ½ mile inland from the seaside, a slight eminence to the N. by NNW. of the village is incrusted with a deposit of from 12 to 18 inches thick of an indurated, much cancellated, ruddy-buff limestone, excavated occasionally for local use, which overlies

a deep layer of earthy, calcareous and concretion-bearing soil, and appears to be part of a denuded miliolite formation, which doubtless immediately overlies beds of the Dwárka Group.

After traversing about ½ mile of arable land in a north-easterly direction, the dark-grey sterile alluvium of the southern terminal branch of the Great Salt Marsh, was once more encountered, and rapidly crossed for 1¼ miles to reach a wide stretch of ploughed plain-land, to re-enter upon another mile of barren alluvium, approaching the SW. bank of the Ojat river. The dry bed of this channel, which wends its way NW., is excavated about a mile or so SSE. of Garej for large irregular lumps of consolidated recent shell sand thickly coated with tenacious alluvium, bearing large quantities of recent shells, principally of the marine-littoral genera *Pholas, Lithodomus, Cardium, Tellina, Mya* and many more. This material closely resembles, and is doubtless a continuation of the deposit already noted as occurring superficially at Sikása,—which is situated about 5 miles farther WNW.— and is used for building huts and cottages in the neighbouring town of Garej. So scarce, indeed, is building material in its vicinity that the inhabitants of Garej generally resort to making large blocks of the ubiquitous alluvial mud, which are simply sundried and used for the erection of their dwellings.

From Garej, which suffers at this time of the year from a lack of drinking water, to be deluged during the monsoons, a water course was found winding W. by WSW. to the E. bank of the Bhádar river where it debouches into the Creek leading still farther W. to Navibandar. Near by this mouth the river was crossed over the substantial lock-bridge to the village of Sikása, and thence to the ferry and back to camp over previously traversed ground.

Tents having previously been sent on to Balej, the Bungalow at Navibandar was quitted on the 9th instant, and a slightly different, somewhat more seaward route was followed as far as Rátia so as to afford an opportunity for examining the sea-shore. The roadway SE. from Navibandar commences at a distance of ¼ mile from the shore and gradually recedes inland towards Rátia which lies upon the ridge of Dwárka limestone ½ mile distant from the sea. On its westward aspect, up to within ½ mile NNW. of Rátia the shore-lands are covered by more or less blown-sand, practically typified by the following method of distribution which was recorded at 1½ miles SE. by SSE. from Navibandar :—Commencing at low-water mark, the sandy beach with its line of Dwárka-limestone breakers, slopes gently upward for about 200 feet where a sudden low scarp, a few feet in height, is developed

in the form of a ridge by the spreading growths of *Ipomæa biloba* and a few tufts of coarse grass. The ridge thus conserved, slopes down at about 40 degrees, to merge into a deeply sand covered plain, where a few *Ipomœas* and an increasing number of small knots of sedges bind the sand together in miniature heaps, each but a few inches high. There is about 100 yards of this flat expanse, of sand which re-caught by the sea breezes, would be blown far and wide inland if it were not for the saving presence of many bushes of *Heliotropium marifolium*, which arrests and holds the sand firmly to form, what has already been described as a *roches moutonnées*-dune. Thereafter the diminished sand is spread but thinly over the land to gradually vanish altogether.

Although an appreciable proportion of blown-sand mingles freely with the soil on the leeward side of the stretch of dunes, the ground, which is flooded during the monsoons, does not appear to suffer from infertility; for it was noticed that this strip of land invariably yields good crops of carrots, chillies, brinjals and even cereals when placed under cultivation, notwithstanding the brackish well-water with which the crops are irrigated at this time of the year.

In the absence of any other route, or of likely noteworthy occurrences out of the beaten track, ground already covered was unavoidably retraversed as far as Rátia Nes; after which the SE. by SSE. roadway was followed to the hamlet of Untra. Here, about 25 yards SW. of the few cottages, there is the remains of a small abandoned quarry, with a deep dried-up well by its side. The exposure thus afforded showed a superficial deposit of about 3 feet of soft, decayed, gritty, brown-grey limestone, underlaid by thick beds of solid, slightly cancellated, hard, ruddy but splintery limestone. The whole of this deposit to a depth of 20 feet, as well as the overlying soft stone, presumably a consolidated blown-sand, evidently belongs to the Dwárka Group of beds, and forms part of the very extensive ridge that runs parallel to the shore line at a mean distance of ½ mile therefrom. Strangely enough, the soft and comparatively valueless, almost rotten superficial stone has alone been extracted and utilised from this site, while the underlying, really strong and durable material has been left severely alone; probably for want of tools, or lack of demand for good building material.

From Untra the road swerves SE. and then E. towards the town of Balej which was observed to be flanked on both sides, (E. and W.), by ridge-like eminences. On approaching Balej, the westward ridge, nearly ¾ mile W. by WNW. of the town was found to be superficially constituted by thick beds of stone,—tilted at an angle of 45 degrees, but

nevertheless merely false-bedded ;—sound and strong-looking enough, but decomposed almost to rottenness to the very core when touched. The stone probably belongs to the Dwárka Group.

Specimens collected and added to the Registered List are as follows:—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
6–4–16	453	Sub-recent Consolidated Raised-dune Sand.	10 to 15 feet Sea-scarp. NW. End of Navibandar Town.
6–4–16	454	Dwárka Limestone. Sandy and Shelly Thick Flagstones.	Breakers at Low-tide Mark. ½ mile NW. by WNW. of Navibandar.
6–4–16	455	Dwárka Limestone. False-bedded Thick Flagstones.	SW. Bank of Bh dar Creek 300 yards. E. of 454.
7–4–16	456	Shell-sand of Beach. Medium grained.	100 yards SW. of Traveller's Bungalow. Navibandar.
7–4–16	457	Dwárka Limestone. Compact. Shelly and Sandy, Thick Flagstones.	Roadside Ridge, 2 miles SE. of Navibandar. False-bedded.
7–4–16	458	Soft, Porous. Decayed to Brown-grey. Gritty Dwárka Limestone. 6 ft. of 2 ft. thick Beds.	Top of Dry Well-shaft on Roadside, 2¼ miles SE. of Navibandar.
7–4–16	459	Dwárka Limestone. Compact. in 1 ft. 6 in. to 2 ft. thick Beds.	Immediately underlying 458.
7–4–16	460	Dwárka Limestone. Coarsely Textured Thick Flagstones.	500 yards WNW. of Rátia Nes and 650 yards from Sea-shore.
7–4–16	461	Dwárka Limestone. Light-ruddy Fine and Cancellated.	200 yards N. by NNW. of Rátia Nes. Surface. 12 to 18 inches.
7–4–16	462	Sub-recent Consolidated Raised-beach Limy-sand.	Bed of River Ojat. 1 mile SSE. of Garej. To depth of 6 feet.
9–4–16	463	Dwarka Limestone. Decayed Coarse, Gritty and Brown-grey.	Surface, Small Quarry. 3 feet thick. Cancellated 25 yards SW. of Untra.
9–4–16	464	Dwárka Limestone. Indurated, Ruddy, Compact but Splintery.	20 feet of 2 ft. 6 in. solid Beds. Perforated. Underlying 463.
9–4–16	465	Dwárka Limestone. Coarse, Gritty, much Decomposed, with Apparent Dip of 45°.	Ridge-slope running from NW. to SE. Nearly ¾ mile W. by WNW. of Balej.

Camp-Station XIX.—Balej.

Field-side, 300 yards SW. by SSW. of the Town.

ON ARRIVAL AT BALEJ on the forenoon of the 9th instant, the tents were found properly pitched, facing due north, as directed, at the edge of a broad wheat-field and by the side of a cool and shady garden, not too close to the town ; and, as everything had been satisfactorily arranged beforehand, work was resumed forthwith, by overhauling, testing, trimming, and packing the specimens that had been collected by the way, as recorded above.

On the morning of the 10th instant, an excursion was taken along the sea-coast lands SE., as far as the village of Gorsar, and from thence inland NE. to Kadach, and back by way of the NE. side of Balej to the Camp, as follows :— A well-shaft near the small *talav* about $\frac{3}{5}$ mile due W. of Balej disclosed a deep layer of soil resting upon a base of solid, cancellated Dwárka limestone ; but the rising ground immediately to the W. of the *talav*, upon which a small *Nes*, or group of shepherd's dwellings is built, was found to be composed of a thin crust, of about 12 inches deep, of a coarse, gritty, brown-grey, honeycombed limestone

Proceeding by a well-beaten cart-track towards the sea-shore, a shallow quarry with an adjoining well-shaft, 500 yards WSW. by SW. of the Nes, or about 4-5 mile WSW. of Balej was next examined, and found to show no less than 25 feet of solid, sandy and shelly Dwárka-limestone, in beds varying from 2 to $2\frac{1}{2}$ feet thick of slightly cancellated structure and medium texture, and this stone was traced seaward for 300 yards WSW. to become obscured by blown-sand, $\frac{1}{5}$ mile from the sea-side, where sand-dunes intervene ; but the Dwárka limestone re-appears, as usual, in the form of big breakers at low-tide mark.

Uniformity of geological structure, as recorded above, characterises the shore borderland right away down to Gorsar, where there appears to be a break of continuity occasioned by the erosion of a former creek. Before reaching Gorsar, however, a roadside well-shaft, $\frac{1}{4}$ mile nearly due W. of the small village of Mocha, was inspected, and noted to be sunk for about 26 feet through thick beds of a slightly cancellated, pale-buff, finely textured limestone strongly resembling a miliolite, but probably referable to the much older Dwárka Group of deposits.

On reaching Gorsar, which is encroached upon by blown-sands, the village was observed to stand upon a substratum of gritty, grey-brown, much perforated and somewhat decayed limestone, probably blown-

sand, which is desultorily dug out for building purposes on the SSE. side of the village, on the NE. side of which a well-shaft discloses the same material to a depth of 15 feet.

From Gorsar the land slopes down decidedly inland north-eastwardly for over $1\frac{1}{2}$ miles to reach a depression 18 feet only above datum, in the midst of which the town of Kadach, surrounded by alluvial deposits, is built. An examination of well-shafts near by and at the bottom of the now dry *talav*, to the immediate SW. of Kadach, showed a substratum of rubbly and then of thin flaggy, compact, ruddy-limestones of fine texture, evidently belonging to the upper portion of the Dwárka Group, but of no commercial value.

The return journey from Kadach, was taken in a NW. by WNW. direction ;—first of all, over $1\frac{1}{4}$ miles of an alluvial plain and afterwards over increasingly rough and rutty, stony ground formed by coarse, ruddy Dwárka-limestones, which gradually became so false-bedded as to apparently dip at places, at an angle of 30°. This was especially noticeable at the superficial excavations on the edge of a ridge of flaggy material, closely resembling the Kunchri-stone, and composed of a compact, ruddy, shelly and sandy limestone of the Dwárka Group, 500 yards N. by NNE. of Rabárikhira ;—whence Balej draws its principal supplies of building stone.

Tents were struck at 6 a.m., and the camp was rapidly transferred to Madhavpur on the 13th instant, where everything was got into satisfactory working order before the close of the day. The town was found crowded to repletion with strangers from all parts of the Province, who had journeyed thither to attend a Hindu festival and fair ; so that some small difficulty was experienced at the outset in catering for camp comforts.

As the borderland between Balej and the sea-shore had already been fully investigated, as far southward as the village of Gorsar, the inland rough route SSE. was followed, skirting the long narrow ridge of rock which runs approximately in the same direction, and which was found by frequent inspections of the ridge slopes and of well-shafts at its base, to be composed entirely of Dwárka limestones, principally of a medium shelly and sandy character, more or less penetrated by perforations, practically false-bedded, and developed in flaggy beds of very variable thickness. As instances of local variations, it may be noted that at about $1\frac{3}{4}$ miles SE. by SSE. of Balej, a roadside well-shaft, near the basal border of the ridge, disclosed no less than 18 feet of solid, but somewhat freely perforated, yet strong and tough Dwárka limestone capable of being extracted in big blocks suitable for general building

purposes ; while farther along, still SSE. at about the parallel of the highest summit of the ridge, (80 feet above the sea-level), and $\frac{3}{4}$ mile NNW. of the village of Mocha, a well-shaft on the level of the plain below, revealed a remnant of only 4 feet of solid stone,—probably the base of the hill-forming strata,—overlying 15 feet of rubbly rock and earthy, limy, conglomerate.

Approaching Gorsar, barely $\frac{1}{2}$ mile farther SE., the long ridge of Dwárka limestone gradually diminishes to practically nil towards the precincts of the village ; where, as already noted, the stone assumes a different lithological character, becoming rubbly, and finally, conglomeratic below. The course of the journey was thereafter altered, and the road S., across an incursion of sand-dunes, was followed to the *Nes* or abode of shepherds, $\frac{1}{2}$ mile S. of Gorsar. At this spot, the ridge of Dwárka limestone gradually rises and continues south-eastwardly for a couple of miles to the height of 79 feet above datum, at Chingaria ; while the intervening borderland, nearly $\frac{3}{4}$ mile broad, is constituted by an undulating rock-plain, the geological structure of which is revealed by sundry artificial exposures , to wit, by a well-shaft on the roadside near Gorsar Nes, which shows 10 feet of solid, slightly cancellated, Dwárka limestone, apparently in only two beds, each about 5 feet thick ; and, about $\frac{1}{4}$ mile SW. by WSW. of Chingaria and nearly 800 yards distant from the shore, where there is an abandoned superficial quarry alongside of a deep well-shaft. The latter shows 15 feet of solid cancellated alternating fine and coarse sub-recent, soft, consolidated shell-sand, similar to that which has been so extensively quarried, (for the erection of the poorer class of native dwelling-houses), along the six-miles of shore-land from near Porbandar City to Kunchri and beyond. Underlying this come the beds of hard shelly and sandy limestone of the Dwárka Group ;—but to what thickness they actually attain, can only be ascertained by core-drilling.

From Chingaria to Páta, the $1\frac{1}{4}$ mile SE. road runs over ground geologically similar in all respects to the preceding line of route from Gorsar to Chingaria ; but it was observed, upon approaching Páta, that the shore-line,—which is broken through by the erosion of a rivulet,—is varied on its NW. aspect by increased accumulations of blown-sand, which surmounting and covering a small elevation of land thereabouts, rises to an elevation of 43 feet above the sea-level, and is collected and held in place in semblance of a group of elongated knolls by the agency of thickly-growing shoots of a stunted variety of the Common or Barbados Aloe,—*Aloe vera.*

After crossing the dry bed of the stream, $\frac{1}{2}$ mile S. of Páta, the roadway once more approaches the sea-shore, at a mean distance of between 200 and 300 yards therefrom, shielded to westward by a long, low, even sand-dune ridge ; while the Dwárka limestone elevations were observed to recede farther inland and to swerve eastward leaving a wide sub-triangular plain, with its base, stretching from their southern termination to the sea-side town of Madhavpur, $1\frac{3}{4}$ miles to the south thereof.

Specimens added to the State Geological Collection are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
10-4-16.	466	Dwárka Limestone. Superficially Decayed. Coarse and Gritty.	Slight eminence, N. side of Nes. $\frac{1}{2}$ mile W. of Balej.
10-4-16.	467	Dwárka Limestone. Shelly. Sandy, Indurated Flagstones.	$\frac{4}{5}$ mile WSW. of Balej and $\frac{1}{4}$ mile from Sea-shore.
10-4-16.	468	Dwárka Limestone. Shelly, Sandy, Compact Flagstones.	1 mile WSW. of Balej and $\frac{1}{4}$ mile from Sea-shore.
10-4-16.	469	Fine Blown-sand of Beach. ..	$1\frac{1}{5}$ miles WSW. of Balej.
10-4-16.	470	Pale-buff, Finely-textured and Slightly-cancellated Limestone.	Surface to 26 feet of Well-shaft. $\frac{1}{4}$ mile nearly due W. of Mocha.
10-4-16.	471	Dwárka Limestone. Grey-brown, Gritty, Rubbly, Decayed.	SSE. end of Gorsar. Stone on which the village stands.
10-4-16.	472	Dwárka Limestone. Ruddy, Rubbly and Shaloid.	150 yards SSW. of Kadach. To depth of 15 feet of Well-shaft.
10-4-16.	473	Dwárka Limestone. Compact, Ruddy thin Flagstones.	Bottom of dry Talav. 60 to 80 yards SW. of Kadach.
10-4-16.	474	Dwárka Limestone. Compact, Ruddy, Shelly and Sandy.	Flagstone Quarry. 500 yards N. by NNE. of Rabárikhira, Balej.
13-4-16.	475	Dwárka Limestone. Shelly, Sandy Compact but Cancellated.	E. edge of Ridge, Virawao. $1\frac{1}{4}$ miles. SE. by SSE. of Balej.
13-4-16.	476	Dwárka Limestone. Shelly and Sandy, compact but Cancellated.	Well-shaft Surface. E. edge of Ridge $\frac{3}{4}$ mile NNW. of Mocha.
13-4-16.	477	Sub-recent, Consolidated Shell-sand. Overlapping 478.	Top of 17 feet deep well-shaft. $\frac{1}{4}$ mile SW. by WSW. of Chingaria.
13-4-16.	478	Dwárka Limestone. Shelly. Sandy and Compact.	Underlying 477 at depth of 15 feet
13-4-16.	479	Slightly Coherent Sand. Base of Aloe covered Dune.	Nearly 1 mile W. of Páta, and 300 yards from Sea-shore.

Camp-Station XX.—Madhavpur.

'Van', NE. Outskirts of the Town.

ONE OF THE BEST POSSIBLE of camping grounds was secured at a place called the 'Ván';—a veritable Banyan-bower on one side with a plantation of tall densely-crowded Coconut-palms on the other. The Banyan-bower is worthy of special notice in this place, as being one of the finest of its kind in the State, if not in the Province. It is constituted by only a couple of comparatively small trees of *Ficus bengalensis*, whose wide spreading branches have thrown down a vast succession of aerial roots, many of which have penetrated into the ground to form huge pillars out-rivalling the parent stem in size. The shady retreat beneath the canopy formed by these twain trees, covers an area of more than 150 by 80 feet, and affords ample space for the accommodation of a fairly large châlet, single-poled tent.

On arrival at Madhavpur, the town and its surroundings were found crowded with a motley throng of visitors to a local Hindu fair called *Madhavrai Meda,* and some difficulty was experienced in domestic camp arrangements, and in procuring attendance for camp and field work, until the close of festivities on the evening of the 16th instant. The brief respite thus occasioned, however, was turned to good account by drafting sketches and mapping in connection with the production of the Third Quarterly Report.

On the 17th instant a bullock-cart was secured for the purpose of carrying specimens while investigating the geological structure of the coastal borderland on foot from Madhavpur southward to the boundary of the State. It has already been recorded that the sea-shore to the NW. of the town, extends towards Páta in a long, narrow, unbroken stretch of low sand dunes, which slope down on the leeward side to a wide undulating rock plain ; but to the SE. of Madhavpur, it was found that the sand dunes encroach inland for fully half-a-mile, forming ridges of high hillocks in the neighbourhood of the town. On reaching one of these eminences, ½ mile ESE. of Madhavpur, a tolerably large open quarry, called Babudi Khán, was revealed where excavations to depths of from 17 to 34 feet, stopped by the underground water-level, afforded ample evidence of the nature of the deposits ; which are nothing more nor less than consolidated accumulations of blown-sand.

Babudi Khán, at its western, most deeply worked 'back' shows a superficial depth of loosely coherent blown-sand, which passes almost

abruptly into freely cancellated, and finally, into compact but soft and porous, light-brown stone. At places, where the surface loose-sand has been blown away by the prevailing winds so as to expose the already cancellated and sub-aerially consolidated stone, subsequent sunbaking has been instrumental in converting the upper parts into very hard and splintery material. The stone from all parts of the quarry, right down to the underground water-level, is usually cut into blocks 18 by 12 by 6 inches in dimensions, and these are sold, at the quarry, at from Rs. 2 to Rs. 2-4 annas, per 100 blocks, and consumed locally for erecting walls and native cottages.

It is both interesting and instructive to observe that the cancellations in this and other raised sand-dunes which have become sub-aerially consolidated, are practically limited to the superficial portions, and differ somewhat in character from the perforations that are found in deposits of littoral-marine origin,—such as those of the Dwárka and Miliolite beds of limestone. They are evidently, for the most part, produced by the bindweeds, sedges, grasses and other plants which play such an important part in preventing the whole of the sand from being blown inland. Some of the larger spaces, moreover, are possibly the remains of the burrows of certain agamoid lizards (*Uromastix hardwickei*) which abound hereabouts.

From Babudi Khan south-eastward to the southernmost limit of the State, the blown-sand encroaches inland, forming sporadic dome-shaped dunes at intervals, for fully half-a-mile, making it impracticable for the roadway to approach any nearer to the shore, which forms an irregular and interrupted sloping beach to the level of the sea. A little farther inland the surface of the ground grows rocky and rugged, with the corrugated upturned edges of false-bedded, indurated, sandy, buff-coloured, very variable beds of Dwárka limestones, which ultimately rise into a multitude of hillocks trending roughly northward from the State-boundary to Mulmadhavpur, 1¼ miles, to tail down westward in the direction of Madhavpur, for about 700 yards. The stone yielded by these hillocks especially on their eastward slopes, frequently exhibits a marked apparent dip from SW. to NE.; sometimes in thick, solid flags suitable for build ing purposes ; but, unfortunately such developments are found to be very limited, and liable to vary suddenly into coarse fissile or splintery textures, so that little if any use has been made, even locally, of the material.

On the 19th instant, after all samples had been trimmed, registered and carefully packed, the exploration of the neighbourhood of Mul-

madhavpur was resumed as follows :—About one mile W. of the village, a large abandoned quarry was examined and found to be nothing more nor less than a complete excision of an inland raised sand-dune from summit to base; a foot or so deep at one end and 25 feet at the other. The stone yielded from this excavation is precisely similar to that now being extracted from Babudi Khan noted above, and would no doubt furnish material durable enough for small native dwellings, if properly laid and plastered with good mortar ;—the materials for which are locally superabundant.

For about a mile to the W., and thereafter to the S. and trending SE. to the boundary of the State, from the village of Mulmadhavpur, are numerous hillocks of a compact ruddy to buff Dwárka limestone, much false-bedded, and flaggy, which only occasionally yield large and sound building blocks, but can nevertheless be turned to profitable account by being excavated within reasonable limits, for kilning into exceptionally strong lime. Much of the superficial soil on these hilly slopes, indeed, is actually converted by epigene reactions into a kind of earthy lime, which is dug out by the villagers as wanted, for plastering the floors and walls of their dwellings.

It has already been recorded, but may here be repeated by way of emphasis, that of all formations in the State, the Dwárka beds, although of inconsiderable total thickness, offer the most puzzling of stone textures and variations in colour and composition. So, in Mulmadhavpur, where the material predominates, it was not surprising to find a fairly large but quite local development of sound and compact flagstones, often from 6 to 8 inches thick, finely grained, and of a pale ruddy-buff, almost white, colour, exposed superficially for a few hundred yards, to within a stone's-throw of the east end of the village. The same stone however when traced northward, soon grows very rough and rubbly, and is not utilised locally because of its superior hardness.

When the outcrop of this stone ceases, it gives place to the appearance aboveground, of a coarsely textured, soft, porous, but incomprehensibly tough, sandy limestone, of a ruddy-buff colour, containing a few thoroughly recalcified fossils of marine molluscan shells, and clearly underlying the compact flagstones as basement or conglomeratic beds. This stone is quarried in pits to a depth of about 6 feet, ½ mile E. of Mulmadhavpur, in blocks of all sizes, but usually 3 to 4 feet by 12 inches and by 6 to 8 inches in dimensions, and sold at the pit sites at 4 annas each. They are only locally demanded for cottage door-steps. Precisely similar stone of slightly better quality is quarried to a depth of 10 to

12 feet, (the underground water-level), exclusively for State use, at the 'Veler Khán,' ½ mile N. by NNE. of Mulmadhavpur.

After visiting the abovementioned sites, the journey was continued northward for the purpose of examining the hilly ridges which trend for 1½ miles from WSW. to ENE., commencing approximately one mile NE. of Madhavpur. These were found to be built up of coarse, false-bedded, flagstones of the Dwárka Group, variable from place to place and so deeply decayed as to offer no temptation to would-be local stone consumers. The final ridge hereabouts terminates abruptly eastward, at a height of 56 feet above the sea-level ; and the land thereafter slopes to a decided depression more or less covered by deposits of alluvial clay for fully 2¼ miles farther E. to the SE. corner-boundary of the State, which extrudes in form of an alluvial area of about 2½ square miles in extent.

Taking the north-westward road from the base of the boundary for ¾ mile to another corner boundary of the State, a small bridged rivulet was found, practically terminating at this spot, eroded deeply through a fine, fresh-grey plastic clay, crowded with the shells of an elongated variety of *Paludina,* and thereby denoting its freshwater origin and suitability for use as superior potter's clay for the manufacture of native earthenware.

Continuing along the level cart-road north-westward hugging the State boundary all the way, first of all NNW. for 1¼ miles, then NW. for ¾ mile, and afterwards WSW. for 1 mile to another corner-boundary, the land westward and then southward was noted to present a flat stone-strewn plain diversified by sundry small and large irregular patches of alluvial deposits ; the roadway was therefore followed sinuously eastward over fitfully cultivated ground derived from a substratum of Dwárka limestone towards the village of Páta. At 2⅕ miles E. by ENE. of Páta, a slight eminence was observed and found to be superficially quarried to depths of from 6 to 12 feet of a soft, cancellated grey-brown stone presenting all the features, already recorded, of consolidated blown-sand. At Páta itself, 100 yards ESE. of the village, a good exposure of the beds forming the high ridge from NW. to SE., was examined and found to be constituted by false-bedded strata of hard, flaggy, ruddy-buff Dwárka limestone of so variable a character, as to be commercially worthless, although quite good enough for local use. Páta village, is built upon the rubbly stone of this ridge, which, although it lies fully ¾ mile inland from the shore, is yet covered pretty deeply at places, notably on the south side within the village, with

marine drift ;—bearing numerous shells of chanks and other recent littoral molluscs.

Proceeding to the seaside due W. of Páta, the sand dunes at a distance of 300 yards from the shore-line were noticed to sweep over an elevation of 43 feet above the sea-level, to form a considerable area, fully 500 yards across, of undulating ground thickly overgrown by the Barbados Aloe, *Aloe vera*, which would without doubt be capable of extended cultivation on the dune tops, with only a mere trifle of attention, and thereby not only bind the sand together but yield revenue to the State by the establishment of a native factory for crude 'Aloe-cake,' which is chiefly exported from Bombay to the United Kingdom and the Straits Settlement.

Turning once more inland, a small quarry was examined about 200 yards or so SSW. of Páta, towards the tailing down on the lee of the shore-dunes. The artificial exposures in this pit disclosed from 2 to 8 feet of soft, grey-brown, consolidated, fine blown-sand overlying from 8 to 10 feet of medium to coarse, pebbly and shelly conglomerate, barely compact enough to hold together when hewn out as building blocks, and manifestly constituting a portion of raised-beach of Sub-recent date.

On the 21st instant tents were struck at Madhavpur, at 6 a.m., and the camp was transferred to the inland town of Kadach, which had been casually visited on the 10th instant, in traversing the countryside intervening from Balej to Gorsar and back by way of Kadach. The NNE. cart-road over rough and rubbly Dwárka limestone was followed along its crescentic course towards Mander, thereby affording an opportunity for thoroughly examining the structure of the ground, westward to the shore borderland and eastward to the boundary of the State.

Confirmatory evidence was taken of the structure of the ridges of Dwárka limestone, (variable, cancellated and compact flagstones, frequently false-bedded), which lie to the SE. of the roadway, while the plain on its westward aspect is covered by thick deposits of freshwater alluvium indicated by the presence, (especially in a small river bed which runs to Páta), of numerous shells of *Unio*, *Planorbis*, and a few valves of *Cyclas*.

Onward and northward, the slight eminence, noted already, on the 19th instant, as occurring 2⅙ miles E. by ENE. of Páta, was re-crossed, but in a northerly direction, and a second small abandoned quarry,—the bearings of which were noted as 2⅞ miles N. by NNE. of Madhavpur,—was discovered, which shed additional light upon the general structure of the underlying strata. The quarry bottom was pierced by three small well-shafts, so that the following results could be readily pieced

together:—For an area of nearly ½ mile in diameter, the alluvial surroundings give place to a dome shaped mound of consolidated blown-sand;—now more than 2 miles distant from the sea-shore. This soft and porous grey-brown stone attains a maximum thickness of 20 feet, riddled with perforations above but compact below. It was only this very poor material that was sought for by local excavators, and when nearly exhausted, the diggings were, of course, abandoned. The bottoms of the well-shafts however show, that the original sand-dune was wafted on to a substratum of hard, thinly-flaggy, ruddy-buff Dwárka limestone, which appears to constitute the foundation beds of the whole of the countryside from the shore, right up eastwards to the boundary of the State.

The abovenoted inference is amply borne out by subsequent testimony as follows :—About 3¼ miles N. by NNE. of Madhavpur, an elongated ridge of precisely similar stone to that found at the bottoms of the 20 feet deep well-shafts, outcrops along the roadside, and is locally called Bhaváni Dhár. The stone is hard, much cancellated and weathered above, and false-bedded, but promises to yield tolerably thick and sound building blocks. It is doubtful however, whether this fairly good material will ever be utilised, because it is not valuable enough to justify quarrying and cartage except for short distances, and is much too difficult to tool for local use.

One mile SE. of Mander the same stone outcrops as subsoil, and large rubbly blocks of it are simply levered up for building purposes; for although the stone also forms the foundations of the town, it there obtains superficially in a completely shattered condition for several feet in depth, and local builders do not find it worth their while to dig deeper.

From Mander to Kadach, similar conditions of rough, rubbly surface prevail till within about a mile of the last named town, which lying in the midst of a depression of what must formerly have been a southerly continuation of the Great Salt Marsh, is practically surrounded by alluvial deposits.

Specimens gathered for the State Geological Collection during the sojourn at Camp-Station Madhavpur are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks
17-4-16.	480	Sub-recent Consolidated Blown-sand of Raised-dune.	Surface, W. end of Large Quarry ½ mile ESE. of Madhavpur.

Date	Registered No.	Provisional Name.	Locality and Remarks.
17–4–16.	481	Sub-recent Consolidated Compact, Blown-sand.	Same site as 480, but 20 ft. below surface of E. end of Quarry.
17–4–16.	482	Sub-recent Consolidated Blown-sand. Hard and Honeycombed.	Same site as 480. Sunbaked surface of E. end of Quarry.
17–4–16.	483	Coarse Shell sand of Sloping Beach	1 mile SE. by SSE. of Madhavpur.
17–[illegible].	484	Blown-sand of Carex-zone of Dunes	1 mile SE. of Madhavpur.
17–4–16.	485	Dwárka-limestone. 3 ft. thick Much honeycombed.	Surface of well-shaft 1½ miles SE. by ESE. of Madhavpur
17–4–16.	486	Dwárka-limestone. Compact Shelly and sandy.	Immediately underlying 485, at 3 to 6 ft. from Surface.
17–4–16.	487	Dwárka-limestone Shelly and Pebbly Conglomerate.	Immediately underlying 486, at 7 to 15 ft. from Surface.
17–4–16.	488	Dwárka-limestone. Fine, Pale-buff. Sandy. False-bedded	E. slope of Hillock 1¾ miles ESE. of Madhavpur
19–4–16.	489	Dwárka-limestone. Fine, Ruddy buff. Flaggy. False-bedded	Low Ridge, nearly 1 mile W. of Madhavpur.
19–4–16.	490	Dwárka-limestone Compact, Pale Ruddy-buff. Big Flagstones	Surface. 100 yds. E. of Mulmadhavpur. Worth prospecting.
19–4–16.	491	Dwárka-limestone. Coarse, Very Porous but Tough. Big Blocks	Surface Pits, 6 feet-deep ½ mile E. of Mulmadhavpur
19–4–16.	492	Dwárka-limestone. Coarse and Porous but Tough, very large Blocks.	Veler Khán State Quarry. ½ mile N. by NNE. of Mulmadhavpur.
19–4–16.	493	Grey-brown Limestone. Indurated and much Cancellated.	E. end of WSW. to ENE. Ridge 2½ mile NE. by ENE. of Mulmadhavpur.
19–4–16.	494	Alluvium of Boundary Nala full of *Paludinæ* and a few *Cyclas*.	3¾ mile ENE. of Madhavpur
19–4–16.	495	Grey-brown Limestone. Fine Blown-sand.	Small abandoned Quarry. 2¼ miles E. by ENE. of Páta.
19–4–16.	496	Dwárka-limestone. Compact. Buff Flaggy, Cancellated. Variable.	100 yds. ESE. of Páta on NE. slope of NW. to SE. Ridge.
19–4–16.	497	Earthy Deposit full of Chank and other Recent Shells	Overlying Dwárka-limestone SE. part of Páta Village.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
19-4-16.	498	Consolidated Blown-sand. 4 to 10 ft. Deposit	Surface of small Quarry. 200 yds. SSW. of Páta.
19-4-16.	499	Recent Consolidated Pebbly and Shelly Raised-beach	Immediately underlying 498.
21-4-16.	500	Dwárka-limestone. Thick Flags. Hard. Cancellated and False-bedded	1⅓ miles NNE. of Madhavpur W. end of WNW. to ESE. Ridge.
21-4-16.	501	Consolidated Blown-Sand. Grey-brown, Cancellated Surface.	2¾ miles N by NNE. of Madhavpur. Small Abandoned Quarry.
21-4-16.	502	Dwárka-limestone. Hard. Ruddy. thin Flags.	Underlying 501, at depth of 20 ft. from Surface.
21-4-16.	503	Dwárka-limestone. Hard. Ruddy, Sunbaked and False-bedded.	Bhayáni Dhár. 3¼ miles N. by NNE. of Madhavpur.
21-4-16.	504	Dwárka-limestone Compact. Ruddy, Thick broken Flags	Surface and Subsoil. 1 mile SE. of Mander.

Camp-Station XXI.—Kadach.

Pipal Arboretum, 300 yards ENE. of the Small Town.

CONVENIENTLY SITUATED as a camping ground, but with little in its favour for geological reconnaisance work, Kadach was chosen as a halting place, partly to break too long and arduous a journey and partly to afford an opportunity for examining the stretch of countryside radiating eastward from the town to the boundary of the State.

Kadach, as already noted, lies in the midst of an alluvial depression, which however ceases at about 300 yards on its east side to gradually rise into a barren rock-plain, more or less thickly strewed with fragments of Dwárka-limestone sub-soil drift. This plain extends for over 1,000 yards to the NE., E. and SE. of the town to descend farther eastward by a slight scarp into a narrow strip of cultivated valley-land to rise again as a rock-plain right up to the boundary of the State. The geological structure of this rock-plain is well exemplified by excavations bordering the slight scarp alluded to above, from which site, called Babudi Khán, stone is extracted for local building purposes. The quarry

cuttings, including a small well-shaft adjoining, show a few feet of rubbly subsoil derived from a total thickness of about 12 feet of tolerably thick flagstones of a ruddy-white colour and compact texture, inclined to be rifty and decidedly false-bedded. The bulk of the material is soft enough to be very easily tooled, but becomes case-hardened by exposure ; and especially so by prolonged sunbaking. Immediately underlying these flagstones there comes a stratum of fully 10 feet of a rubbly conglomerate, with numerous fossils of shells of marine molluscs, which together with their matrix have undergone complete re-calcification by the infiltration of dissolved lime from above.

It may be noted in passing, that the upland drainage channels, which form considerable watercourses southward along the Barda-Alech vale, break up into numerous rivulets which periodically discharge their waters into the main body of Porbandar's Great Salt Marsh ; so that in the event of a very heavy rainfall season, the low lying lands around Kadach stand in danger of being overwhelmed by floods. Such a disaster indeed, it is locally stated, occurred only as recently as September 1914, when the camping ground, known as Brahmachari's Wari and its temple and sacred tank were submerged to a depth of over 10 feet and almost utterly destroyed ; while the deserted town was also practically left in ruins.

At the moment of writing the entire district is on the verge of drought there being only one small well at the bottom of the *talav* on the SW. side of the town, whence a poor supply of slightly muddy but potable water is available. To remedy this among other greater evils, ought not to be either a costly or a difficult engineering feat ;—a feat that would, of course, entail the reclamation of the Great Salt Marsh.

Such a project it is needless to note, would, upon its completion, immediately revolutionise the Revenue Department of the State. It would involve the damming of but a few creeks and minor outlets in the shorelands, and the construction of a controllable system of reservoirs and canals, and improvement of existing water courses inland. The reclaimed land, although largely, saliniferous, is already rich and deeply soiled enough, to be rated, as soon as available, at a premium for market-garden produce and quick returns ; while heavily paying crops, such as those of the Sisal Hemp, would grow and flourish on the soil just as it is, to prepare the way for cereals and cotton-growing grounds. Cocoanut and other fruit trees would naturally be established as a matter of course.

In anticipation of a long, wearisome and nugatory journey, tents were struck at Kadach at 5 a.m. on the 24th instant, with a view to

examining the untraversed areas N. of Kadach and E. of the Great Salt Marsh as far as the village of Mitrála. Considerable difficulty was experienced upon nearing the proposed destination, by reason of the numerous impassable though dry watercourses, which rendered frequent detours imperative. The first serious obstacle to be encountered, but not capable of being overcome, was presented by the river Bhádar, about $1\frac{1}{3}$ miles SSE. by SE. of the town of Bhád. The stream was full of salty-water, and although there was a ferryboat available at "Kundli-ka-Tar," as it is called, it would have taken up more time than could have been spared to take advantage thereof, so as to reach Mitrála before the close of the day. It was also noticed that the women of Bhád were busy on the river terrace digging pits from which to scoop out water for domestic wants ;—such water, of course, being fairly well freed from brackishness by a process of natural filtration.

It was therefore deemed necessary to take the E. cart-track to Jamla and then NNE. to Chatráwáo, both in Junágadh territory, and to thereafter cross the ford of the Bhádar westward into Porbandar State, by exceedingly rough and circuitous by-ways, to eventually reach Mitrála;—which is situated only one mile distant from the boundary. On arriving at Mitrála, no suitable spot for a camping ground could be found, and the women of the village were seen trooping with head-poised water-vessels to the neighbouring village of Delodar. Hence it was resolved to pitch the camp at the last-named place ; and night had fairly set in before tents could be got ready for occupation.

Shortly after leaving the stone-strewed plain to the N. of Kadach the ground gradually assumed a thoroughly alluvial character, as far as the eye could reach on either side of the NNW. roadway. Not a vestige of stone could be discovered outcropping through the alluvial deep-grey deposits, N., S., E. or W.; but it may be presumed that those deposits directly overlie beds of the Dwárka Group of arenaceous limestone. The towns and villages ;—Garej, Bhád, Mitrála and Delodar are, one and all, built upon mounds of alluvium, which, suffering pitifully at present from an insufficient water-supply, are, during the monsoons literally deluged almost beyond endurance ;—for, it was elicited, at Delodar, as a 'case-in-point,' that the inhabitants are annually held prisoners in their homes for a month or so by the encircling floods of water ! The exceedingly poor 'haul' of only a couple of specimens for the State Geological Collection was consequently secured during the stay at Camp-Station Kadach as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
22-4-16.	505	Dwárka-limestone. Compact. Soft, Ruddy; in thick Flags.	Babudi Khán 1000 yards. NE. by ENE. of Kadach
22-4-16.	506	Consolidated Fossiliferous Conglomerate. Very Rubbly	Underlying 505 at depth of 10 to 15 feet

Camp-Station XXII.—Delodar.

By side of Talav. 100 yards E. of the Village.

PORBANDAR'S GREAT SALT MARSH OR WASTE,—which is annually flooded during the SW. monsoons by the influx of sea-water from the open ocean on the west, mingling with the fresh surplus drainage of the uplands at the north and from the east—is projected on the sheets of 'The Indian Atlas' of the Great Trigonometrical Survey, like a gigantic *Amœba* taken from the pages of a text-book of zoology, with its nuclei and vacuoles represented by stony eminences, and its pseudopodia extending in all directions, but principally branching south-eastwardly.

During the dry season, the bottom of this vast pond is revealed in form of an extensive barren plain, more or less deeply covered by deposits of saliniferous, but otherwise, richly fertile dark-grey alluvium, which, without its branching diverticula, may be roughly estimated to occupy an area of more than 80 square miles. There is likewise evidence to show, that nearly the whole of the State territory to the south-east of the Great Salt Marsh must have been included within its far-reaching limits, and this statement can perhaps, be nowhere better exemplified than by an examination of the countryside sub-centralised around and about the village of Delodar.

Although not so rich as 'regur' or decayed volcanic material, the deeply deposited alluvium, naturally reclaimed during the past few centuries, by reason of the gradual elevation of the land, is yet fertile enough to yield large and profitable crops of cotton, cereals, market-garden produce and fodder for cattle; but the agriculturist is heavily handicapped during the few months preceding the rains by a woeful lack of water; while during the rains, he gets 'too much of a good thing.' At Delodar and for many miles around, there are no well-shafts; simply because, by digging through the alluvial deposits to the lower under-

ground water-level at 15 feet or thereabouts, brackish, if not quite salty, water is invariably met with. The villagers are therefore entirely dependent upon their *talavs*, (for potable water) which, as the days go by, become desiccated. When that happens,—as at the present moment,—all that can be done, is to dig down to a limited depth of not more than 10 feet, to catch the remnant of the fast subsiding surface water before it percolates to saliniferous depths. At the bottom of the Delodar *talav*, there are at present half-a-dozen small pits, each about 10 feet deep, with puddles of from two to three feet of fresh but muddy water in them. These pits are thronged from dawn till dusk by a succession of women and children, who come from near and far to fill their drinking water vessels ; and, as most of them quaff the dirty water without filteration or even allowing the impurities to settle down, so as to draw off the purified supernatant liquor, it is stated that much preventable disease becomes rife during the dog-days.

An examination of the *talav* deposits, as typical of the entire countryside, showed an alluvium of marly dark-grey clay, crowded with the shells of estuarine and marine molluscs :—*Ostrea, Cardium, Tellina, Cerithium* ; added to which are local freshwater forms,—*Paludina* and *Cyclas,* and a land shell or so. These deposits indubitably show that they must once, probably within historic times, have been formed by the agency of the then far more extensive Salt Marsh, and that like the sediments of the latter, they rest upon a substratum of Dwárka limestones. Samples of the deep layer of sunbaked mud forming the bed of the Hugli Vokala, (branching off from the Bhádar River, and which discharges into the Great Salt Marsh), were collected for future detailed examination in the laboratory, and provisionally found to be composed of very finely divided matter, showing no trace of organic remains, and closely cracked into angular, indurated fragments by prolonged sunbaking.

From Delodar as a centre, the westward quadrant of countryside, for a radius of nearly six miles, is traversed by no less than half-a-dozen branching and sub-parallel rivers with the wide channel of the perennial Bhádar to the South, and the expanded, shallow mouth of the Minsar at the north ; thereby constituting an extensive riparian delta opening out into the Great Salt Marsh. On the 26th instant, the highways and by-ways of this extensive area were rapidly covered, frequently over pathless land, to avoid deep ditches and stream beds, and it was observed that the whole of the ground consisted of deep deposits of principally freshwater alluvium, very largely under preparation for

cultivation. The local agriculturists state, that seed is not sown until the monsoon floods subside : but that germination and growth in the fertile soil is very rapid, so that the staple produce of cotton and cereals amply repays for risks that sometimes become serious.

Plentiful and continuous supplies of water for irrigation in this part of the State, it is admitted, would speedily transform the great tracts of land into prosperous farmsteads, and it is therefore suggested, that by the construction of a series of strong dams across places of vantage on the principal watercourses, and locked channels of intercommunication between the reservoirs thus constituted at different levels, so as to provide for adequate circulation and prevention of stagnation, the surplus monsoon freshwater could be conserved and controlled in such a way, as to effectually put an end to disastrous periodic floods and turn the water-supply thus acquired to good and profitable account. This would indeed be a first step towards the complete and speedy reclamation of land already being very gradually restored by the agency of natural elevation.

On the 27th instant, tents were struck at 6-30 a.m. and the camp was transferred to the town of Kandorna, which it will be remembered, was formerly,—for a couple of days at the end of July, 1915,—made a centre of observation. Needless to note, the ground covered had not been traversed before, and although nothing of importance was anticipated, the criss-cross-country course taken, was adopted for the purpose of fixing the geological boundaries of the outcropping and their underlying strata as accurately as possible.

From Delodar to Erda, the ground was found to be deeply alluvial, and presumably resting upon the fast vanishing beds of Dwárka limestone ; but on reaching Pádardi $1\frac{3}{4}$ miles farther NW. the alluvium of the Great Salt Marsh on the westward side of the village was observed to be blown by the prevailing winds in form of a very fine, almost impalpable sand of a dark-brown colour, into a kind of inland dune, and arrested in a succession of closely-set mounds, like *roches moutonnées*, by tufts of hardy grass struggling for a bare existence.

About $1\frac{3}{4}$ miles WSW. of Pádardi, the large and important river Minsar, shallowed down considerably and embanked by only from 2 to 3 feet of alluvium, widens out into a channel of nearly a-quarter of a mile in breadth before discharging into the Great Salt Marsh, and offers thereby a substantial nucleus, for the construction, by damming, of a very extensive freshwater reservoir, which could be maintained as such by deepening, rip-rapping and finally by stone and cement lining

to conserve the enormous floods of pure mountain water brought down and annually allowed to go to waste. To minimise losses by evaporation and percolation the stone and cement lining of the lower portions of the reservoir ought to suffice ; but in order to prevent putrefaction as the season advances, the conserved water ought, of course, to be kept aerated by circulation. This can best be done at the outset by means of a few effluent locked canals made to flow into smaller reservoirs at lower levels ; but the time would eventually come, (when means accrue through vastly improved irrigation), for the installation of an adequate pumping-station, with ramifications to the remotest parts of the State

At Pádardi itself the alluvium immediately west of the village, is no longer underlaid by Dwárka limestones, but rests directly upon much decayed bedded-lavas of the Deccan Trap Period. This is clearly shown by a well-shaft at the bottom of the *talav* on the W. side of the village, which at a depth of 10 feet yields, at present, a poor supply of brackish water, oozing out from beds of much decomposed, zeolitiferous, amygdaloidal lava. The E. side of Pádardi village assumes quite a different character ; as the highly decomposed bedded-lavas are exposed at the surface and probably reach down to the abysmal depths of some hundreds of feet.

Progressing N. by NNE., the surface of the ground maintains its volcanic character up to Kerála and thence eastward for about ¾ mile to the boundary of the State. Towards the SW. side of the village there are deep deposits of detrital matter closely similar to those of the Great Salt Marsh alluvium ; while the two big wells at the bottom of its adjoining *talav* yield such brackish and partially stagnant water, at the present time, from depths of 15 to 20 feet, that the inhabitants are obliged to dig small pits into the detrital soil to salve a meagre supply of muddy water of questionable wholesomeness for domestic needs.

From Kerála, the broad acres of fertile volcanic soil stretching to Bápodar WNW., were next carefully examined, fortunately by the help of a few newly sunk well-shafts, and the ground was thereby shown to be composed of deeply decayed bedded-lavas, a curiously altered purplish variety of which, from the compact zone, was collected at a depth of 12 feet from the surface, where the rock commences to disintegrate into rubbly subsoil. Westward of Bápodar, as already noted the ground gradually gets covered by alluvium.

Eastward of Bápodar, for a distance of a trifle over 2¼ miles, to the boundary old-site of Asiáwadar, the surface of the land becomes gradually

more plainly, volcanic by reason of the increasing freshness of the exposed beds of lava ; but, on the north-eastern track towards Kandorna, sure signs, of the near presence of miliolite deposits are to be seen in the ever increasing fragments of that stone which bestrew the ground in every direction ; until the deposits themselves encrust the surface in thick beds of obliquely laminated stone upon which the large district-town is built.

Specimens secured for the State Geological Collection from Camp-Station Delodar are as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
25-4-16	507	Marine and Freshwater Recent Shells from Alluvium.	Bottom of Talav. E. end of Village of Delodar.
25-4-16	508	Alluvium. Sunbaked Deposit ..	Bed of Hugli Vokala. S. of Delodar.
27-4-16	509	Decayed Amygdaloidal Lava. Underlying Alluvial Soil.	W. side of Pádardi. Bottom of 10 ft. deep well shaft in Talav.
27-4-16	510	Altered Lava of the Compact or Middle Zone.	1 mile WNW of Kerála. Bottom of 12 ft. deep new well-shaft.

Camp-Station XXIII.—Kandorna.

District Bungalow, N. Outskirts of the Town.

WITH THE EXCEPTION of the small area of countryside surrounding the route NNW. by NW from Kandorna to the village of Aniáli, the whole of the State lands in the neighbourhood of this Station of observation have now been fully examined and reported upon. It being close upon the end of the month however, it was decided to make the District Bungalow at Kandorna a temporary halting place rather than a centre for observation, with the two-fold object of sending the clerk to headquarters for the purpose of adjusting monthly accounts, and of affording the writer an opportunity for piecing together the evidence gathered concerning the geological structure of the entire coastal borderland of the State, for publication as a "Third Quarterly Report," which would otherwise lack completeness. The work of the "Third Quarterly Report" now being actively compiled will be continued during the absence of the clerk, until his return to Kandorna on the 3rd May, 1916, when the camp will be removed to Khambala in the Barda Group of hills.

DIGEST OF DIARY.

May, 1916.

GEOLOGICAL OBSERVATIONS in the immediate neighbourhood of Kandorna having been completed upon a former occasion (towards the close of July, 1915), it only remained to cover some of the same ground for the purpose of securing, if possible, better specimens of the compact stone of Dhának Dhár, and to take a few photographs on the banks of the River Minsar, which here exhibits the false-bedded miliolite base resting upon an earthy conglomerate full of fragments of black stone. This work was done on the 27th April.

At the end of the month the clerk of the Department was sent to headquarters for the purpose of adjusting the monthly accounts, and a few free days were thus secured to the writer and fully utilised in the quiet well-kept District Bungalow, at Kandorna, for the compilation of his Third Quarterly Report ;—a duty involving much time and labour in piecing together the evidence, just gathered in its entirety on the geological structure of the coastal borderland of the State.

On the 5th May, the camp was transferred to the breezy heights of Khámbala on the south-eastern flanks of the Barda Hills, which is best approached along the vale of the Dhángawa Vokala, a tributary to the River Minsar. The journey thence was taken across hitherto untraversed ground from Kandorna to the small village of Aniáli ; but nothing of any consequence could be recorded save that the surface of the land grew rough and rutty from the presence of coarse miliolite-base beds resting upon concretionary and conglomeratic layers, overlying the bedded-lavas of the Deccan-trap Period. These miliolite beds occasionally rise into low, narrow ridges, which obstruct the straight courses of the country cart-tracks, notably at about $1\frac{3}{4}$ miles NNW. by NW. of Kandorna, $\frac{3}{4}$ mile farther N., and about 1 mile SE. of Aniáli. From Aniáli to Bordi, the formerly traversed cart-road was followed NNW. past the divaricating eastern spurs of Cocahia Dhár, and thereafter WNW. along the S. bank of the Dhángawa Vokala which sweeps around the S. and W. ends of the village of Bordi, where it is spanned by the Railway-bridge.

New ground remained to be investigated between Bordi and Khámbala ; and, to that end, the crescentic NW. by WNW. route was chosen ;—mainly over rough, solid, stony ground formed by the truncated columns of coarse, tough granophyre, which every here and there emerge in the

form of mounds of huge boulders and isolated pillars that have best withstood the ravages of time. It was therefore with some difficulty, in the absence of prospecting appliances, that only tolerably fresh samples, sufficient to indicate the precise characters of the stones, could be secured by dint of perseverance with sledge and trimming hammers; and for these and similar situations throughout the Barda Group, it may be noted that nothing short of diamond drilling and blasting can possibly avail, if perfectly fresh and sound samples, *i.e.*,—samples that are not decayed by atmospheric agents or altered by monsoon conditions and sunbaking,—are wanted.

Samples of a light grey-brown, coarsely-textured but very tough and strong granophyre, were gathered from an eminence of boulders and pillars, protruding boldly from the surface of the ground, about $1\frac{3}{8}$ miles NW. of Bordi, as a site suitable for quarrying operations, within reasonable distance from the Railway-line. The stone at the surface although weathered and full of miarolitic spaces and products of alteration and decomposition, has been sunbaked to a high degree of hardness and is yet tough enough to be broken into an angular shingle of gauges suitable for high-grade road-metalling. By blasting, it is more than probable, that an intensely tough, grey granophyre, in blocks of very large sizes adapted for building the piers of bridges and for dock and harbour construction could be readily extracted.

At the present moment, the sites in this, and the neighbourhood of Bordi, offer good opportunities for the introduction and development of a particularly large and varied series of massive stones of the granophyre and kindred types;—but cartage conveyance, even as far as to Ránáwao Station, would be prohibitory. As a case in point, it may be noted, that a particular sample of finely-textured, light-grey granophyre from Cocachia Dhár near Bordi was specially desired for road-metal by the Chief-Engineer of Karachi Municipality, who offered Rs. 5 per ton for partially broken boulders, f. o. b., at Karachi. It was found, that although massive stone from the vicinity of Ránáwáo Station could be profitably quarried, entrained and shipped to Karachi at the price offered, the excess for cartage from Cocachia Dhár to Ránáwáo Station would bring bare expenses up to a trifle more than Rs. 7 per ton;—the consignment could not therefore be sent.

As many other favourable quarry-sites exist in the immediate neighbourhood of Bordi, on the N. side of which the Railway-line passes, it is here suggested that a loading platform, if not a permanent Station, should be opened without delay at the village.

Passing northward for about $\frac{3}{4}$ mile, a couple of hills rise prominently from the upland plain, approximately 2 mile NNW. of Bordi, the highest of which is 435 feet above the sea-level. These elevations, as parts of an outlying ridge running northward along the boundary of the State, and locally known as Jaderra Dhár, are composed of a coarsely textured, white granophyre, which acquires a rusty colour by exposure, and is intensely tough and difficult to break. The surface stone however is deeply decayed, but there can be no doubt, that large supplies of big blocks of sound material could be readily secured by excavations on the hillside slopes. Farther westward, in the direction of Khámbala, the same stone, much decayed and full of alteration products, has been desultorily dug out of the ground ; and being so far decomposed as to become comparatively soft and easily tooled has been used for making small bridges and in embanking a waterway leading towards the village of Khámbala.

A tedious up-hill drive, past new and old Khámbala, along the base of the great dam of the Khámbala Talav, and thence by a circuitous cart-track, led to the State Bungalow, which was selected as a centre for observations. The specimens collected were duly trimmed, packed and registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
5-5-16	511	Light Grey-brown, Coarse-textured Granophyre.	Low Eminence. Roadside Surface. $1\frac{3}{8}$ miles NW. of Bordi.
5-5-16	512	White Granophyre. Closely Resembling No. 72.	Jaderra Dhár. Two Outliers 2 miles NNW. of Bordi.
5-5-16	513	Altered Granophyre of Character like 512.	Surface Excavations, 300 yards W. of 512.

Camp-Station XXIV.—Khámbala.

State Bungalow, Summit of Dhori Dhár.

PERCHED ON A PLATFORM at the summit of a moderately high hill called Dhori Dhár, about half-a-mile south of the present village of Khámbala, the bijou State Bungalow, although built almost to the points of the compass, is sheltered on the east by the slightly

higher hill, Chagaro Dhár, 557 feet above datum ; and on the SW. by the range of heights stretching towards Ránáwáo. Nevertheless, as the veranda and small portico-frontage faces W., presumably for the sake of the widest view of the *talav* amid its amphitheatre of hills, it catches the direct rays of afternoon sunlight and nearly the full force of the prevailing SW. wind.

During the month of May, and presumably throughout the dry season, the bottom of the broad hill-bound valley, presents an arid area of equilateral triangular form, with sides of about 1¼ miles in length. The apex of this space points toward the State Bungalow and its consort hillock called Gadhia Dhár, some 6 or 7 hundred yards to the NW., and has been closed by a high earth-and-stone dam, to form a great reservoir for the monsoon surface drainage, known as the Khámbala Talav.

Khámbala Talav is at present practically dry, save for a couple of fairly deep patches of water at either end of the high embankment ; and into these pools there run the channels of two streams, the smaller of which called the Vasara Vokala, receives the drainage of the hill-slopes on the S. and SW. sides of the valley ; while the much larger watercourse collects the rainfall of the runnels on the N. side of the *talav*, and, as Vijfaria Jhár, has its source in the heart of the hills, along the vale of Sáthvirda Nes and beyond, for fully three miles NW. of its affluence into the *talav*. Along the northern portion of the *talav* and piercing beneath the high embankment, the stream, now known as the Vijfaria Vokala, wends its way north-eastward through a fertile highland dale to add its waters (locally called the Thorania Vokala) to the greater channel of the Bileshwari Vokala, 500 yards or so E. by ENE. of the picturesque village of Asiapat, which stands by the cool banks of the usually perennial riverside, 1¼ miles W. of the boundary of the State.

These geographical details have here been entered with a view to the proper appreciation of the somewhat intricate structure of the countryside ;—charming and productive enough along its well-watered rocky slopes, but barren to the point of desolation at the summits and plateaus of its sub-centrally situated groups of high hills, where the vegetation at this season is represented by dry grasses and stunted growths of the Rán tree, *Mimusops hexandra*, and a few clumps of the Male bamboo, *Dendrocalamus strictus*. In some of the valleys, however, where a deep soil of felsitic sand is developed, many excellent fruit trees thrive ;—notably the Mango, *Mangifera indica* ; the sweet Karaundá, *Carissa Carandas* and the Jungle Jámbu, *Eugenia lanceolata*.

At dawn of day, accompanied by four villagers from Khámbala an excursion on foot was taken over the hills, on Sunday the 7th instant, for the purpose of recording the geological structure of the centrally situated elevations to the W., NW., and N. of Khámbala.

Descending from the Bungalow to the dry bottom of the *talav* near by the foot of the high embankment, the deep pool of water there situated was found to be quite green with the zoospores of freshwater *Algæ*; while numerous birds were observed feeding on the fish and water-weeds; conspicuous among which were large assemblies of the Painted Stork, *Pseudotantalus leucocephalus*; many large and small Egrets, *Herodias intermedia* and *H. garzetta,* some still retaining their dorsal plumes; a few Little Cormorants, *Phalacrocorax javanicus,* the slightly rank flesh of which is sometimes eaten; and a wild duck or two among which the Shoveller, *Spatula clypeata,* was identified.

True lacustrine deposits are seldom met with in the practically lakeless Province of Kathiáwár; but the Khámbala Talav, notwithstanding, furnishes tolerably typical samples, of sub-recent and Recent sedimentary accumulation, that are worthy of more than a passing notice. The bottom of the dry *talav* exhibits a thin layer of detrital felsitic sand, derived directly from the disintegration of the rocks of the mountain-massive; and this sand is crowded with myriads of the dead turreted shells of *Potamides* many of which bear traces of a thick periostracum.

Sundry small well-shafts, as well as the 15 to 18 feet W. scarp of the Vijfaria Vokala,—hard by where the mountain-rill enter the *talav,*—disclose the nature of the underlying lacustrine deposits; which have accumulated to the maximum depth of about 15 feet, and are composed of alternating layers of spongy and shaly grey-coloured, sandy and marly-clays, bearing the remains of the small freshwater shells noted above. Samples of these deposits were secured for future laboratory examination.

One mile to the west of the *talav* embankment, where the gorge of the Gelanser Dhár forms the mountain stream-bed of the Vijfaria Jhár the rapidly rising uplands, in a succession of mounds and ridges, has been made the dwelling place of a band of shepherds whose circular stone huts with grass-thatched conical roofs lend a curiously picturesque aspect to the scene, with its bold background of lofty hills. This permanent shepherd's camp is known by the name of Khára Virá Nes; and it is commonly believed that the great west scar of Gelanser Dhár which towers above, was the work of the " God of the lightning and thunder,"

a kind of Hindu Zeus,—who sent his fiery darts to rive the hill asunder Be that as it may, the beetling cliffs of the scar on the western side of the mountain-pass, affords a very fine illustration of columnar jointing on a large scale ; the rock itself being composed of an exceedingly tough texture of the granophyric type. The pathway on the eastern side of the gorge is steep and often narrow, but yet sufficient to afford a foothold for camels and pack-ponies ; but, following the course of the stream a wide valley ere long is reached at another shepherd's camp-village called Sáthvirda Nes, where a small State Bungalow, very poorly furnished and State Police-quarters have been established.

Sáthvirda Nes lies approximately 2¾ miles NW. by WNW. from Khára Virá Nes, and its scattered huts are clustered around the valley of the Vijfaria Jhár on ridges above the reach of the swollen stream during the rainy season. These ridges, and indeed the slopes and summits of the numerous hills around and about, are composed of exceedingly tough and strong grey granophyres of medium to coarse textures ; but perfectly fresh specimens are difficult to get, on account of the prolonged weathering to which the surface stone and detached boulders therefrom has been subjected. Some of the huge vertical columns exhibit spheroidal shrinkages on a gigantic scale ; and when, after ages of exposure, the spheroids become detached and fall out, large circular chambers are left patent in the sides of the columns. Spheroidal shrinkages, however, are not so frequent in these centralised coarsely grained rocks, as in the spurs and outliers of the group of hills. Occasionally, dyke-like structures may be observed traversing the main massive, and are conspicuous by reason of their closely set transverse joints, which give rise to a coarse kind of cleavage.

From Sáthvirda Nes a general survey of the surroundings disclosed the fact that the assemblage of hills which form the core of the group, offer but scant variety either in the texture or the mineral composition of its rocks, which may therefore be classed together as medium to coarse-grained granophyres. These rocks constitute the main masses NNW. for a couple of miles past the old sites of Vijfaria Nes and Thori-Virda Nes right up to Khoriar Nes at the boundary of the State ; and also stretch westward to Malak-na-Wáo, and the summit of Suli-na-Páni, ½ mile farther NNW., which rises to the height of 1,438 feet above the level of the sea. The flat summit of Malak Dungar, ¾ mile SSW. of Suli-na-Páni, must likewise be included in this category ; although its westward spurs, which were formerly examined* exhibit variations

* On 23rd and 25th November, 1915.

which were duly observed and recorded ;—many of them being of distinct economic value, and one, near by Godhana, revealing the rare structure known to petrographers as orbicular.

To avoid covering ground already just traversed, the return journey from the confines of the State around Sáthvirda Nes, was made along craggy by-paths over the hills to the NE., in the direction of Chámodra Nes, and after crossing a small plateau surrounded by the summits of hills in this sub-central region of the Barda Group, a SE. track was followed, leading to the W. side of Hathia Dhár,—so called on account of the fancied resemblance to an elephant *couchant,* from whence an easy descent was made to the *talav* by the side of the isolated conical hill called Gadhia Dhár, and thence along the top of the high embankment to Dhori Dhár Bungalow.

On the morning of the 9th instant, the tents having been previously sent to Asiápát, the journey thence was taken along a roundabout route for the purpose of examining the hill-spurs and outliers to the SE. of Khámbala, which had not hitherto been visited. A halt was called at the village of Khámbala, which is built upon the denuded tops of great columns of granophyre of medium to coarse texture, forming a hillock called Kári Dhár, which is in reality a small spur extending northward from Chagaro Dhár situated just behind the Bungalow. The stone of this spur has been deeply weathered and sunbaked ; but is yet quite tough and strong enough to yield an abundance of tolerably good and durable road-metal. The effect of weathering has been to bleach the mineral units and render them soft and friable, while the counter influence of sunbaking of the hydrated mass has been not only to harden the altered texture, but to create sundry small spaces within its substance by shrinkage ; and these miarolitic cavities invariably become the seat of development of many small secondary crystals and curious alteration products. In such situations gems are sometimes formed. The original fresh rock, which can only be obtained by drilling and blasting, is without doubt a grey granophyre of the best quality for positions where great strength of materials is indispensable.

Passing south-eastward along the rough and rutty cart-road from Khámbala to Ránáwáo, at a distance of 1¾ miles from the last-named village, an eastward spur from the mountain massive stops short of the W. side of the roadway in form of a low hillock of exposed columnar rocks and spheroidal boulders, locally known as Fakáda Dhár. By reason of furnishing a good site for quarrying operations coupled with its proximity,—1¾ miles NW.,—to the Railway-line at Bordi, the stone

here available in abundance, is worthy of special attention, as it consists, even at the surface, of a fairly fresh, compact and sound, mottled, blue-grey granophyre capable of yielding large blocks suitable for dock and harbour construction ; while the wastage would constitute the best-possible of high-grade road-metal extant.

On the opposite or ENE. side of the roadway, another small eminence, barely noticeable as such, is covered with broken blocks of quite a different character, and can be traced to form the westward sloping spur of an outlying hill near by, called Ladha Dhár, which rises approximately $1\frac{5}{8}$ miles SE. by ESE. of Khámbala. The stone of the basal spur appears to be in a perfectly fresh and sound condition with but few rifts and weathered dislocations ; but the summit rock shows signs of being deeply decayed, being quite fissile at the surface. When blasted, however, there can be no doubt that an enormous supply of thoroughly sound material would be yielded of a distinctly ornamental character, essentially similar to the so-called incipient orbicular granophyre, No. 34, of the Ádatiána Heights near Ránáwáo.

From Ladha Dhár the cart-road due north was taken to Bileshwar, past the already traversed region of Jaderra Dhár and a succession of low outlying ridges of more or less deeply altered granophyres, typified by the coarsely textured whitish stone SSE. of Bileshwar and the similar but more finely-grained rock to the immediate WNW. of the village of Asiápát.

Samples secured for the State Geological Collection were duly registered as follows :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
6-5-16	514	Alluvial Deposit. Sunbaked. ..	Dry Bottom of Khámbala Talav
6-5-16	515	Concretionary and Shaly Alluvial Lacustrine Deposits	Underlying 514. NW. end of Talav Opposite Bungalow.
7-5-16	516	Grey-brown Granophyre Extra-tough and strong	Bed of Vijfaria Jhár. 600 yds NNW of Khára Vira Nes.
7-5-16	517	Altered Granophyre White. Pink and Miarolitic.	Same stone and from same site as 516.
7-5-16	518	Pale Grey Granophyre. ..	.. Base of Crags, Vijfaria Jhár.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
7-5-16	519	Felsitic Sand from Coarse Granophyre.	Bed of Vijfaria Jhár, ¼ m. ESE. of Sathvirda Nes.
7-5-16	520	Grey Granophyre. Medium-textured, Tough and Strong	Hill-side Spur 500 yds ENE of Sáthvirda Nes.
7-5-16	521	Much Altered, Cleaved, Dyke-rock	Plateau, 500 yds. SSW of Hathia Dhár
7-5-16	522	Granophyric-felsite Slightly Sun-baked to Purplish grey	Base of Gadhia Dhár. 1,000 yds NNW of Khambala Bungalow
7-5-16	523	Granophyric-felsite Fresh, Pale, Blue-grey	Base of Dhori Dhar State Bungalow Hill, Khambala
7-5-16	524	Cleaved Granophyric-felsite Pale Blue-grey.	Summit of Dhori Dhar State Bungalow Foundation.
9-5-16	525	White Granophyre Altered by Prolonged Weathering	S side of Khámbala Village. Hill-spur called Kári Dhár
9-5-16	526	Highly Altered Granophyre ..	Same Rock and Site as 525
9-5-16	527	Light-grey Granophyre Good Quarry Site.	Fákada Dhár, 1¾ miles SE. of Khámbala and 1¾ miles NW. of Bordi.
9-5-16	528	Spherulitic Granophyre	20 yds. ENE of 527
9-5-16	529	Spherulitic Granophyre Weathers into Flakes.	Summit of Ladha Dhár, 1⅝ miles SE by ESE of Khámbala
9-5-16	530	Coarse, Whitish Granophyre Partially Altered	Surface Outlying Low Ridge-spur 600 yds. SSE of Bileshwar
9-5-16	531	Fine, Grey Granophyre Much Decomposed Superficially.	Surface of Outlying Spur, 500 yds WNW of Asiapát.

Camp-Station XXV.—Asiápát.

NW. Bank of Bileshwari Vokala, 100 yards S. of the Village.

CHARMINGLY SITUATED on the NW. bank overhanging the waterside of the sparkling, mountain-fed stream called the Bileshwari Vokala, the village of Asiápat, built upon a foundation of huge truncated columns of granophyre and fringed on its southern aspect by a deposit of the miliolite-base, was chosen as a centre for final

observations on the geological structure of the central and eastern group of the Barda Hills comprised within the boundaries of Porbandar State.

Tents were found pleasantly pitched under the shade of a venerable mango tree, within a stone's throw of the rippling stream, at noontide on the 9th of May, and everything having been got into good working order, the succeeding couple of days were devoted to the compilation of this report from the diary and field note-book; while arrangements were likewise made for a long excursion on foot into the " heart of the hills " rising to the respectable height of 1,148 feet on the WNW.

At 7 o'clock on the morning of the 12th instant, a couple of bullock-carts and 4 men, as guides and coolies, accompanied the surveying party north-westward along the uneven track skirting the N. bank of the Bileshwari Vokala, gradually running dry. The scarp on this N. bank, descends sheer down for 17 feet to the bed of the stream, which runs over the shorn ends of gigantic columns of coarse granophyre, covered at the scarp-top by a crust of miliolite, full of fragments of the mountain-massive on which it rests. The S. bank of the stream shelves gently upwards as a stony terrace, largely clothed with a kind of leguminous tree, *Pongamia glabra*, which is accounted to be valuable for the preparation of " Indian Pearl-ash." The dry ledge of a water-fall hard by, looked as though good specimens could be easily detached from the angular edges presented temptingly to view; but when the sledge hammer was brought to bear upon them, nothing save weathered samples could be secured.

It was specially observed that the miliolite deposits,—denuded down to their very base, and appearing as mere crusts of stone full of grains and fragments of the mountain-massive; sometimes overlying the ancient subsoil layers of the latter, and at others resting directly upon the solid-rock in all its pristine freshness,—assume, along the valley of the Bileshwari Vokala and its surroundings, a level varying from 247, at Bileshwar Village, to nearly 300 feet above datum. These facts lend additional and strong support to the conclusion that the Pleistocene sea must have submerged the entire region around the Barda Hills to the miliolite limit-mark of what is to-day 300 feet or so above the level of the sea. The flat plain stretching eastward, with occasional outcrops of outlying ridges of the mountain-massive, is deeply overlaid with detrital felsitic sand and earth, but nevertheless strongly suggestive of the presence of the older series of bedded-lavas of the early part of the Deccan-trap Period, through which the later hypabyssal rocks

were thrust. This is indicated by the practically horizontal patches which lie between the hill-spurs, surround the outliers of the mountain-massive and become continuous with the plains of bedded-lava of the countryside beyond.

Ascending by a steep foot-path to the base of the lofty hill called Babia Dungar, the summit of which is situated nearly 3 miles WNW, 'as the crow flies,' from Asiápát, the entire mass of the great core of the Bardas, of which this forms a fractional part, appears to be constituted by a coarsely textured, but exceedingly tough grey granophyre, severely weathered to a whitish colour, and exhibiting numerous separations of iron-ore and other alteration products, the true nature of which remains to be discovered by both chemical and optical analyses.

There can be no doubt that the enormous development of this grey granophyre, in a variety of fine, medium and coarse textures, would form an inexhaustible source of supply of stone suitable for situations where exceptional strength of materials is required ; but, for the present, the sites are practically inaccessible. Fortunately, however, stone of essentially similar character, outcrops at lower levels, along the entire base of the hills, by the side of which cart-tracks already exist.

Proceeding northward along the base of Babia Dungar by the foot-path swerving W. to the shepherd's retreat, called Azmápát Nes, it was found that a great spur from the summit, stretches NNE. for considerably more than half-a-mile, and, as such offshoots from the main mass usually exhibit modifications of structure, samples from the top and bottom of the spur were carefully examined and discovered to be excessively tough, strong, and of a distinctly ornamental character ;—similar indeed in all respects to sample No. 65, which was provisionally registered as a mottled spherulitic and granophyric-felsite. At this new site, however, the stone occurs in greater abundance and is much fresher, especially in the valley at the westward base of the spur, locally known as Krishna Jhár.

Another noteworthy feature of the rock of this spur is, that on its westward aspect approaching Azmápát Nes, the mass exhibits a coarse kind of cleavage into a parallelopipedal shingle, which however could not be obtained in a fresh condition without recourse to blasting ; so that only weathered samples were secured for future laboratory examination. This great spur appears to have been thrust through the already existent mountain-massive under conditions of great lateral pressure, thereby resulting in the transverse cleavages abovenoted ; while the original intrusive or dyke-rock assumes, by its wearing-down,

the outward aspect of a series of steps, or *páts*, as they are termed in the vernacular ;—hence the local names, Asiápát, Azmápát, Kháripát.

On reaching Azmápát Nes, which lies in the valley nearly $1\frac{1}{2}$ miles SSE. of the most northerly boundary of the State in this central hilly region, it was observed that a high ridge, (Hadio Dhár) which runs practically E. and W., marks the divide between the States of Porbandar and Navánagar, and is constituted by coarse granophyric rocks, essentially similar to those of Babia Dungar, and the assemblage of adjacent hills and heights. The shepherds, or more correctly goatherds and buffalo-keepers at this time of the year, usually desert their huts at Azmápát Nes to seek the shade and shelter of a few Banyan Trees, from the scorching sun, at some distance down the valley called Nur Jhár, which takes a southward course separating Babia Dungar on the E. from Káládongar at the W.

Káládongar rises to the height of 1,148 feet above the sea level, being thus 108 feet higher than its twin hill, Babia Dungar, and evidently a part of the same intrusive or dyke-mass, separated into two by the erosion of Nur Jhár. The wide valley thus formed holds a deep talus of felsitic earth and detached fragments of rock from the heights on either side, and supports a robust vegetation of Karáundá bushes and Jungle Jambu ;—the fruit of which, however, is not sufficiently esteemed to be of any market value. There can be no reason why these fertile mountain recesses should not be utilised for the cultivation of suitable varieties of fruit trees, which require little or no attention beyond their establishment to yield a plentiful supply of wholesome edible fruit ; as the soil is unquestionably rich enough ; while the underground water-supply rarely sinks to depths that cannot be reached by the roots.

Along the vale of Nur Jhár, for more than a mile on either side, the summit slopes of Babia Dungar on the E., and of Káládongar at the W., afford numerous sites suitable for the excavation of large open quarries from which practically inexhaustible supplies of very large blocks of a varied assortment of tough and durable granophyres of the highest economic grades could be readily extracted. For the present, however, these sites are inaccessible, but their existence is here recorded in anticipation of the future opening-up of suitable roadways.

On the 15th instant, a final excursion was taken north-eastwardly from Asiápát to cover the remainder of the untraversed ground around that centre of observation. The journey, by reason of the rough and hilly nature of the ground, was made in part on foot ; while the level patches of land were covered with less fatigue in a bullock-cart, which

was also found of service for the conveyance of the specimens collected.

After a run round the windings of the rivulet, up to about half-a-mile N. of the village of Bileshwar, it was noticed that the high-banks of the stream were more or less covered by tolerably thick deposits of conglomerates and obliquely laminated thin beds of the miliolite-base resting upon the decayed surface of the mountain-massive, and thickly clothed at places with the conspicuous flowering climber *Cryptostegia grandiflora*, of which little is now heard ; although, about a generation ago, it was reported to yield a beautiful fibre ; while its latex was found to contain a goodly proportion of rubber. The leaves and tender shoots of the plant, however, are so notoriously poisonous that even hungry goats refuse to feed upon them.

Proceeding NNE. in the direction of Sajanawála Nes, a halt was called 1½ miles NE. by NNE. of Asiápât, towards the centre of a flat expanse of land, almost encircled by ridges and other outlying outcrops of the mountain-massive. An area of well-soiled ground at this spot under cultivation, called for the sinking of a new well-shaft ; and, as already surmised, it was found that the strikingly flat surface was caused directly by the occurrence of horizontally disposed bedded-lavas immediately below ;—while these being in proximity to the subsequently intruded hypabyssal rocks of the elevated regions, were found to be harder, by reason of extended induration, (sub-contact metamorphism), than the bedded-lavas of the general countryside.

The artificial section exposed by this well-shaft, showed from the surface downward :—(i).—2 to 3 feet of calcareo-siliceous soil, derived from detrital washings of granophyres and felsites, which may be called "felsitic-earth", mixed with the disintegrated limy soil of the miliolite-base deposits below. (ii).—About 1 foot of decomposing, rubbly miliolite full of fragments of both hypabyssal and volcanic origin. (iii).—Volcanic subsoil to a depth of about 4 feet, infiltrated with lime. (iv).—An appreciable thickness of amygdaloidal lava in a fairly fresh condition, crowded with sub-spherical zeolitiferous amygdales. (v).—Compact, hardened, bedded-lava in an almost perfectly fresh condition.

Another well-shaft, some 300 yards SSW. of Sajanawála Nes, showed miliolite deposits to the depth of 10 feet ; while the NE. bank of the hill-stream flanking the S. side of the shepherds' village, also revealed deposits of the miliolite-base, fully 9 feet deep. The miliolites at these parts directly overlie the bedded-lavas, but they also overlap the adjacent spurs and outliers of the mountain-massive farther afield.

Taking the rough cart-track which leads northward from Sajanawála Nes, for a trifle over a mile to the boundary of the State, it was observed that the ground is rendered hilly in all directions by a succession of ridge spurs radiating southward from the heights of Ránásar Talav and Ránásar Dhár, 732 feet above the level of the sea. These spurs, as already mentioned, are not only generally accessible for quarrying operations, but usually abound in valuable varieties of stone ; so that it was not surprising to find good utilisable developments, which could be profitably exploited as soon as a few traffic routes are established. Finely-textured granophyres of the highest-grades occur in abundance in the immediate neighbourhood of Sajanawála Nes, and the other more westward spurs from Ránásar Dhár, while the rock forming the elevation on the S. side of Ránásar Talav, consists of a very dark, almost black felsitic stone full of elongated porphyritic crystals, probably of pyroxene, the true nature of which awaits determination. The precise sites suitable for excavation along these hill-spurs, were duly noted, and samples from each site accurately registered and provisionally named.

It may be casually noted that Ránásar Talav at this time of the year was found to be fairly full of water in a semi-stagnant condition, crowded with water-weeds, and of a bright-green colour due to the presence of countless microscopic zoospores of freshwater *Algæ.* The Ránásar Heights and the Jhár or gorge leading southward therefrom exhibited a distinctively upland flora;—conspicuous amongst others being the Bastard Teak, *Butea frondosa,* in full foliage ; and, lower down, close growths of shrubby-trees of *Acacia senegal, A. ferruginea,* and the closely allied *Dichrostachys cineria* with its strikingly beautiful hermaphrodite inflorescence in pink and yellow ; while interspaces were fully occupied by three or four kinds of *Cassia,* the ubiquitous *Zizyphus nummularia* and another variety of wild Jujube, *Zizyphus xylopyrus;*—all of them indicative of the fact that the soil and general conditions are suitable for the cultivation of economic plants.

On the return journey from Ránásar Talav, a westward and then southerly course was taken along the base of the high-hills and their numerous spurs ; and among other sites from which samples were gathered, a specially good position for a fairly large quarry of fresh and strong blue-grey granophyre was registered as occurring in the form of a nether hillock at the SE. base of Ghoda-Lánki Dhár, near by Fatal Talav Nes, approximately 1¼ miles ENE. of Babia Dungar Summit.

Tents were struck at 8 o'clock on the morning of the 17th instant, and the return journey to headquarters was accomplished during the

afternoon of the same day; the route taken being made to cover the only remaining portion of untraversed ground in the State ;—namely the area bordering the base of the Barda Group of hills from the spur called Fakáda Dhár, $1\frac{3}{4}$ miles NW. of Bordi, to the hill-pass and Railway-cutting near the base of Piára Dungar, known as Javantára Gárá.

Fakáda Dhár spur has already been noted as a suitable site for the opening of a quarry to supply building-blocks of a very superior light-grey granophyre, within easy distance of Bordi. The spur runs WSW. by SW. to the base of Gared Dhár, where the rock assumes a coarser texture, and obtains in gigantic columns, very much weathered and altered superficially, but well adapted for being blasted to yield abundant supplies of dock-building stone, of a deep-grey colour in its perfectly fresh condition. From this spur, at a distance of about 2 miles from Bordi, a secondary short spur taking a NNW. to SSE. direction, and also available as a quarry-site, yields a medium-textured brown-grey stone, which shows signs of developing into an ornamental condition of the character provisionally registered as a mottled blue-grey and buff, granophyric felsite, Nos. 65 and 538. There can be no doubt that the deep-seated, perfectly unaltered portions of the mass are of a uniformly grey colour ; but that it acquires its varied hues through epigene reactions.

Sundry additional specimens, showing structural peculiarities in the outcropping Dwárka Group of marine deposits, in the neighbourhood of Virpur by the side of the Ránáwáo high-road, were finally secured and registered in completion of the State Geological Collection.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
12-5-16	532	Pale Buff-grey Granophyre. Partially weathered.	NW. end of Asiápát Opposite the Police-quarters.
12-5-16	533	Miliolite-limestone Base. Resting on Granophyre-conglomerate.	S. side of Asiápát. Top of N. bank of Bileshwari Vokaia.
12-5-16	534	Miliolite-limestone. Resting on Granophyre-conglomerate.	$\frac{1}{2}$ mile N. of Bileshwar. Top of N. bank of Bileshwari Vokala.
12-5-16	535	Pale Buff-grey Granophyre Weathered and Sunbaked.	Waterfall. Bed of Vokala, $\frac{3}{4}$ mile N. of Bileshwar.
12-5-16	536	Altered White Granophyre. With Iron and Secondary Products.	Base of E. slope of Babia Dungar.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
12-5-16	537	Granophyric-felsite. Mottled Blue-grey and Buff.	NNE. spur from Babia Dungar
12-5-16	538	Granophyric-felsite. Mottled Blue-grey and Buff.	Krishna Jhár, 1 mile NNE. of Summit of Babia Dungar.
12-5-16	539	Granophyric-felsite. Cleaved and Decomposed.	½ mile E. of Azmápát Nes, Barda Hills
12-5-16	540	Altered Granophyre. White, due to Incipient Laterisation.	Bed of Nur Jhár, near Azmápát Nes.
12-5-16	541	Coarse, Whitish Granophyre Altered by Weathering.	E. slope. Base of Káládongar.
15-5-16	542	Amygdaloidal Lava. 10 ft from Surface of Well-shaft.	1½ miles NE. by NNE. of Asiápát and 800 yds. from Sajanawala Nes.
15-5-16	543	Compact Bedded-lava.	Underlying 542.
15-5-16	544	Miliolite-limestone. Base. ..	Overlying 542.
15-5-16	545	Miliolite-limestone. Base 10 ft. deep Deposit.	300 yds. SSW. of Sajanawála Nes.
15-5-16	546	Ruddy-grey Granophyre. Fine-textured. Sunbaked.	Small Mound. 50 yds. NNE of Sajanawala Nes.
15-5-16	547	Brown-grey Granophyre. Fine-textured. Sunbaked.	500 yds. NNE. of Sajanawála Nes, called Kambiála Dhár.
15-5-16	548	Cleaved Granophyric-felsite. Surface. Sunbaked.	500 yds. NNW. of Sajanawála Nes.
15-5-16	549	Partially Cleaved Felsite. Small Spur-mound.	550 yds.NNW.of Sajanawála Nes.
15-5-16	550	Compact Porphyritic Felsite. ..	Slope. S. side of Ránásar Talav.
15-5-16	551	Pale-grey Granophyric-felsite. Slightly sunbaked.	Spur of Ránásar Dhár, ¾ mile NNW. of Sajanawála Nes.
15-5-16	552	Blue-black Felsite	¾ mile NW. of Sajanawála Nes.
15-5-16	553	Blue-Grey Granophyre. Fresh, Medium-textured.	SE. base of Ghoda-Lanki Dhár. Adjoining Fatal Talav Nes.
17-5-16	554	Brown-grey Granophyre. Medium textured. Sunbaked.	Spur from SE. slope of Gared Dhár. 2 miles W. of Bordi.
17-5-16	555	Coarse, Grey Granophyre Superficially Altered.	NE. to SW. Spur from Gared Dhár 2 miles W. of Bordi.

Date.	Registered No.	Provisional Name.	Locality and Remarks.
17-5-16	556	Fossiliferous-Flagstone. Dwárka Group.	Surface. 200 yds. W. of Virpur Side of Ránáwáo Highroad.
17-5-16	557	Dwárka Limestone. Ruddy, Mottled. Conglomeratic.	500 yds. W. of Virpur. NW. side of Ránáwáo Highroad.
17-5-16	558	Dwárka Limestone. Of Kunchri and Degám Type.	1 mile WSW. of Virpur. NW. side of Ranáwáo Highroad.

QUARTERLY REPORT

ON

THE ECONOMIC GEOLOGY OF PORBANDAR STATE

BY

E. HOWARD ADYE, F.G.S., ETC.,

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June, July and August, 1915.

A FIRST TRAVERSE or geological reconnaissance has now been made of the sub-central portions of the State, extending from headquarters in Porbandar City, *via* Ránáwáo and Bordi to the boundary township of Kandorna;—thereby constituting four Camp-Stations, from which observations on the structure and petrography of the countryside have been duly recorded.

In this summary of results, it may be explained that the initial routes of traverse were chosen, not haphazard, but with a view to verifying, as speedily as possible, the forecast that the region selected would be prolific in favourable sites for the exploitation of quarries of merchantable stone, hitherto left untouched by reason of lack of reliable information; but nevertheless of such high intrinsic merits as to justify the expectation that when once sufficiently made known, they would command the stone markets of India in their own particular class.

Porbandar State has long been famous in the annals of architecture as the original home of the incomparable limestone technically termed "Miliolite;" but also, and more appropriately called by commercial men, "Porbandar-Stone." The extensive series of quarries at the heights of Ádatiána, perhaps the largest of their kind in the world, will, as soon as all collateral infor-

Economic Attributes of "Porbandar-Stone."

mation can be gathered, furnish the theme of a special descriptive and petrographical study in the sequel. Economically considered, the stone, in its various grades, has long been recognised to hold an unshaken premier place among the building stones of India, as applied to the erection of frontages and the walls of public-buildings and dwelling-houses generally. In all such situations, Porbandar-Stone stands pre-eminent; and, in this transitory world of ours, its best grades may be reckoned to remain unimpared and to long outlast the lives of many generations.

On account of its physical properties and chemical constitution, however, Porbandar Stone, (which has a hardness only barely exceeding that of its chief constituent,-carbonate of lime,-about 3 on Mohs's scale), except when it contains a superabundance of sand, is comparatively worthless for use in situations that are subjected to severe wear and tear,-attrition and stress,-such as for foundations, floors, steps and landings, pavements and roadways, and in the construction of embankments, bridges, harbours and docks. For such purposes, only the strongest, toughest and most durable of materials ought to be indicated.

Strength of Materials in the Light of Modern Researches in Applied Petrology.

The term "Granite" has so long and so persistently been associated in the popular mind with all that denotes great strength, that even professional engineers and architects now-a-days are apt to be misled in their choice of suitable materials, by the specification (doubtless correct), that the tendered stone is a *granite*. In the light of recent researches in applied petrology, the porphyries and porphyrites unquestionably rank highest, closely followed by the diabases and basalts; while the granites come in as a "bad third" in this "struggle for supremacy."

Applied petrology, as distinct, although but a special branch of the science of rocks, further teaches, that the grouping of economic stones into grades, is dependent, not so much upon the chemical composition of the material, as upon its texture and the mutual relationship of its units. This again, in its turn, leads to the more

PLATE I

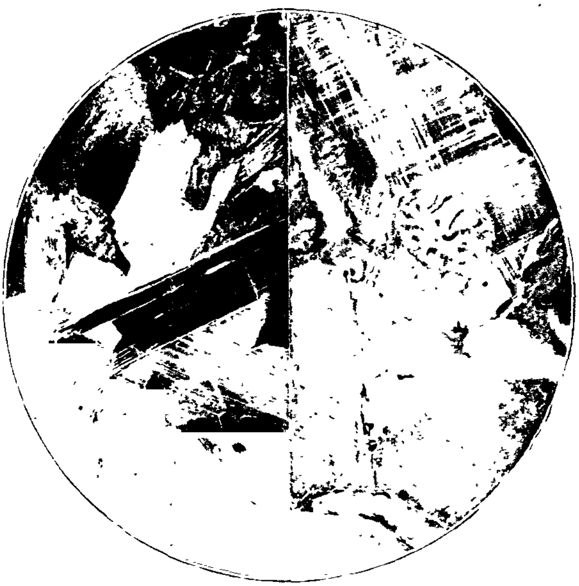


Fig. 1. —The Grey Granite of Aberdeen, Rubislaw Quarries, Aberdeenshire.

Original Camera Lucida Drawing by E. Howard Adye, F. G. S., etc. Magnified 55 diam. and slightly reduced.

Left-hand Semicircle, viewed by ordinary transmitted light.

Right-hand Semicircle, between crossed nicols ;—polarised light.

To exhibit the thoroughly holocrystalline texture of a typical Plutonic or Abyssal rock ; where the mineral units are distinct, and leave no unindividualised material between their members.

philosophic problems concerned with the nature and origin of rocks, the solutions for which can only be sought for and found by careful observation and experiment.

It thus happens that when an essentially acid magma becomes consolidated deep down in the "bowels of the earth" under extraordinary conditions of pressure and temperature, the resulting mass thus slowly solidified, becomes more or less thoroughly crystalline, or, in scientific parlance, *holocrystalline* ;- in which the mineral units are completely separated without leaving any unindividualised material between them. When these crystals consist mainly and essentially of one or more alkali felspars, quartz and a ferro-magnesian constituent, such as mica, hornblende or augite, in fairly large coarse crystals, the rock is called a *granite*, but if the crystals are too small to be distinctly separable by the naked-eye, the mass is termed a *microgranite*.

Holocrystalline Rocks Defined and Exemplified.

When the molten magma happens to be less acid, distinctly alkaline, basic or even ultrabasic in constitution, and subject to similar conditions of consolidation to yield holocrystalline textures, the resulting masses are recognised by petrographers under the distinctive names *syenites, diorites, gabbros* and *norites* and *peridotites* ; and all of these types, including the granites, are collectively classed as *Abyssal* or *Plutonic Rocks*.

Abyssal or Plutonic Rocks Generically Classified.

These brief explanations are not intended to serve as a primer of petrology, but are here entered as a desirable introduction to the proper understanding of the sequel by practical men, whose every-day business leads them to the borderland of systematised knowledge.

Under conditions of less tardy refrigeration and subject to consolidation under an appreciable relief of pressure, the same molten-magma which would otherwise became holocrystalline, may be changed, according to the rapidity of congelation, into anything from a glass, (pitchstone), to a granophyre or granophyric granite. It may be conceived that a deep-seated molten mass

Hypabyssal Rocks Defined and Classified.

of material undergoing secular refrigeration into a true granite, or other plutonic rock, finds certain parts of weakness in the crust of the earth, and naturally forces its way along the lines of least resistance, mainly towards the surface of the earth;—but only to be consolidated before it reaches an outlet. Such dykes, sheets and bosses when consolidated at varying intermediate depths, have been correctly classed together as *Hypabyssal Rocks*; and according to the degrees of crystallisation of their mineral constituents, are severally known as *Pitchstones, Felsites, Porphyries* and *Porphyrites, Diabases* and *Lamprophyres*;—in conformity with the acid or more basic character of the original molten-magma.

Volcanic Rocks Defined and Classified.

When, however, the molten-magma, either acid, sub-acid, basic or ultra-basic is projected near to the surface, or to be even ejected through the surface of the earth, it consolidates, according to the rapidity of cooling into distinctly acid lavas, called *Rhyolites*; less acid lavas, known as *Trachytes* and *Phonolites*; intermediate lavas, typified by *Andesites* and questionably by *Dacites*; basic lavas, familiarly termed *Basalts* including *Dolerites*; and lastly, ultra-basic lavas of the nature of *Magma-Basalts* typified by the *Limburgites*.

Massive or Igneous Rocks Encountered during the First Traverse.

From the introductory information, concerning recognised facts recorded above, it will be readily understood and fully appreciated, when it is stated that the massive or igneous rocks encountered during the first traverse already accomplished, belong mainly to the class of Hypabyssal Rocks, and to the families of Felsites, Porphyries and Porphyrites; while the Volcanic Rocks, in comparatively small development are represented by the family of Basalts and Dolerites.

Among the hypabyssal rocks that have hitherto been discovered, all of them are of economic value, but of varying degrees of

PLATE II

Fig. 2.—North side of Railway-cutting, ½ mile ENE. of Ranawao Station.

Photograph taken 6th September, 1915, at 11-30 a.m.

To show the fresh cores or nuclei of spheroids, with their concentric shells and intermediate substance, rendered more apparent by weathering, in a typical hypabyssal rock (No. 96), of the Barda Group of hills. These spheroidal shrinkages in linear succession constitute the columnar structure, due to vertical jointing of the mass. The major axis of the spheroidal core on the left-hand side of the picture, measures approximately 3 feet.

utility and subservient to special purposes; while the basalts and dolerites are also merchantable though less valuable and more restricted in their applications to everyday wants.

Before the absolute values of individual samples can be registered, each specimen will have have to be subjected to laboratory tests and careful microscopical determinations; but, in anticipation of results, it is desirable that a few further details should be succintly elucidated, with a view to an exact appreciation hereafter. First of all, it may be observed that the hypabyssal in common with certain of the volcanic group of rocks are essentially of an intrusive character mainly manifested in the form of dykes thrust through superincumbent structures. When these dykes or sheets assume gigantic proportions, the vast bulk of the rock is invariably divided by more or less vertical joints, mainly due to contraction during cooling, to form huge columns, which in their turn divide transversely into cuboidal masses; while continued refrigeration results in a series of individual shrinkages within each subdivision intermittently, so as to result in a spheroidal nucleus surrounded by concentric shells of matter. These structural peculiarities become most apparent after exposure to atmospheric influences; and the breaking down of the rock-mass into sub-soil and soil by the processes of *weathering*, as it is called, furnishes an unerring clue as to the utility or otherwise of any given stone to the eye of the practised prospector.

Columnar Jointing and Spheroidal Shrinkage of Intrusive or Dyke-rocks.

Weathering or Atmospheric Influences on the Wearing-down of Igneous Rocks.

When therefore, the exposed surface of a dyke of massive stone whether of hypabyssal or volcanic origin, exhibits a succession of large rounded boulders or spheroids each measuring over a foot or so in diameter, the stone-prospector would do well to test the spheriods with a sledge-hammer, (from 7 to 14 lbs. in weight); and it will generally be found, that after the removal of more or less decayed interstitial matter, the outer concentric

Preliminary Tests for Sound Stone, applied to Igneous Rocks.

shells of the spheroid will break away with increasing difficulty from without inwards, until a sub-spheroidal core or nucleus of practically fresh and sound stone is left. These nuclei may, as a rule, be utilised for economic purposes, unless, of course, the weathering has gone so far as to decompose the entire structure into soil; but, by digging deeper to the zone of underlying subsoil, a goodly proportion of valuable material may invariably be rescued, until the solid rock of the dyke is reached and blasting becomes imperative.

Selection of Sites for Quarrying and Mining.

Needless to note, quarrying operations ought, preferably, to be commenced on the slope of a hill-side or ridge; and not, unless unavoidable, upon level land; so as to allow for natural drainage; and *ergo*, the prevention of subsequent water-logging of the works. These remarks, of course, apply more particularly to the generality of massive rocks other than those that assume a bedded or stratified character. In the latter instances, and in excavating for special beds of sedimentary stone, seams of coal and horizontally or sub-horizontally disposed structures, *mining*, rather than quarrying operations, from a level surface, can be carried on to the best advantage.

Peculiarities in the Jointed Structure of Small Dykes

There is another, and most important factor to be borne in mind, when prospecting for economic massive stone, in this connection, viz.,–when comparatively small dykes,–say, of about 20 to 50 feet or so, are found favourably situated. These dykes, especially of volcanic, but also occasionally of hypabyssal origin, frequently yield an abundant supply of sound merchantable stone of exceptionally good quality; but are liable to escape notice, or to be rejected when met with, for want of careful examination. Such dykes usually exhibit a central portion, rudely jointed into large vertical columns, subdivided as a rule by transverse cracks and spheroidal shrinkages, so as to afford large, and sometimes gigantic blocks, capable of being blasted and trimmed into building-stones of even extraordinary dimensions; while their late-

Fig. 3. -A Typical Granophyre, Wadwala, Alech Hills, Kathiawar.

Photomicrograph of a Preparation by E. Howard Adye. Magnified 20 diam.

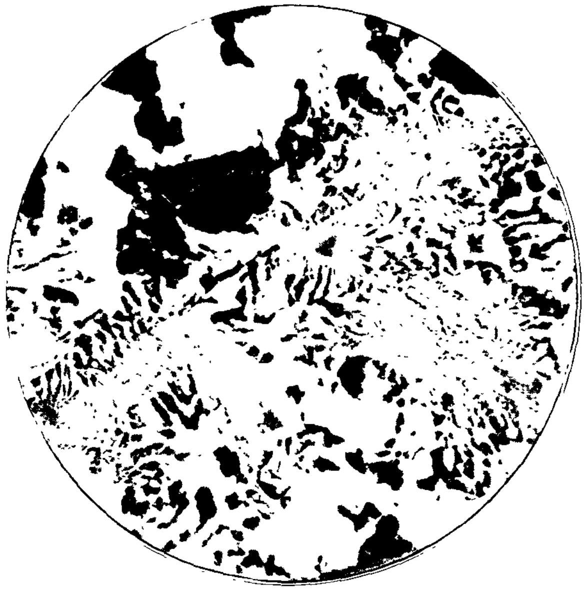
The upper portion of this figure shows the crystals of quartz, (colourless) and ruddy-grey orthoclase felspar, intergrown to form the *pegmatitic structure*, which is visible as such to the naked eye; but the bulk of the field of view,--the lower portion,--is composed of *micropegmatite*, very clearly resolved by this power of 20 diameters into intricately interlocked felspar (shaded) and quartz (clear), forming well-defined "centric-systems" around nuclei of orthoclase felspar. A texture showing micropegmatite in these dimensions, denotes a rock of exceptional toughness and strength. When the dominant felspar is of the nature of orthoclase, the rock, as in this case, belongs to the petrological group of *Porphyries*.

Fig. 4.--Sunbaked Granophyre, Summit of Abapura Dungar, Barda Hills.

Photomicrograph from a Preparation by E. Howard Adye. Magnified 20 diam.

When closely scrutinised, the dominant portion of the field-of-view shows that the rock-mass is essentially similar in structure to that of Fig. 3; but although magnified equally, the texture of the micropegmatite can only be just barely discerned, forming centric-systems around nuclei, (two of which are shown), which have been altered, (laterised), by sunbaking, into deep-red opaque masses of, presumably, former orthoclase felspars. This phase of structure may be regarded as but a single step in advance from the *felsitic* or *cryptocrystalline* to the *granophyric*, and indicates, that although the mass may be much tougher than a granite, it is inferior in strength to the more advanced stage shown in Fig. 3, and is prone to prove slightly brittle and to splinter under sharp blows, or to pulverise under intense crushing force.

PLATE III.



ral parietes, invariably of much finer texture, are liable to split into small parallelopipedal slabs, or even to be cleaved like a slate, and then into an unutilisable shingle. This happens most frequently among volcanic dykes; but the lateral edges of small hypabyssal dykes, seldom become cleaved into slabs of less than an inch in thickness; so that when met with in a fresh condition they present advantages rather than otherwise to prospectors in quest of road-metal.

Further, when dykes of less than 20 feet in width are encountered, and even when they occur in veins of but a few inches in thickness, they need not therefore be discarded; because, when unweathered, many of them, notably in the region of the bedded-lavas, are found to be composed of exceedingly compact and tough basalts which readily break along their unseen joints into polygonal pieces, admirably adapted for use as road-metal. Instances of these various modes of occurrence, in dyke-rocks of both hypabyssal and volcanic origin will be duly recorded in the sequel.

Polyhedral Jointing in Small Dykes.

It has already been observed that the utility of a stone, insofar as strength and durability are concerned, depends less upon its chemical composition than on its texture and the mutual relationship of its mineral units; and the truth of this statement can scarcely be more strikingly exemplified than by a detailed examination of phases in the evolution of the granophyres that are so abundantly in evidence in the Barda group of hills, within the boundaries of Porbander State.

Strength and Durability Dependent upon Texture rather than on Chemical Composition.

Petrographers are familar with the fact that when a mass of granite or other plutonic rock sends forth intrusions into its surroundings, the dykes or veins so formed invariably exhibit what is known as the *granophyric structure*; or, in other words, an intergrowth of its quartz and felspar constituents. It has further been found that wherever such structure obtains, the rock-mass acquires added

Granophyric Structure.

strength and durability; but that these properties are dependent upon the texture,—coarse, medium or fine,—of the intergrowths. When the texture is sufficiently coarse to be plainly visible to the normal naked eye, the structure is technically termed *pegmatite;* but when it is too fine to be detected without artificial aid, it is called *micropegmatite.*

Pegmatite and Micropegmatite.

Economically considered, micropegmatite, (which is characteristic of the group of rocks known as granophyres), may be taken as the determining factor in optical analysis, insofar as the strength of the structure is concerned. The strength of the sample, moreover, is not only proportionate to the presence, in quantity, of the micropegmatite, but to the degree of its development, *e. g.*, when the micropegmatite is very clearly shown, and also furnishes the dominant feature in the field of view under a magnifying power of from 20 to 25 diameters, the rock-mass may unerringly be pronounced to be stronger and tougher than when the micropegmatite can only be barely resolved as such, under the same powers of the microscope. Needless to note, it is assumed that the materials under observation are in a perfectly fresh and unaltered condition.

Definition of Granophyre, with Tests for Strength determined by Microscopic Structure.

The term "Granophyre" will therefore hereinafter be reserved to denote rock-structures in which the granophyric element or micropegmatite occurs as the dominant constituent; and it will be found that the strongest granophyres are those in which the micropegmatitic portions are neither too coarse nor too finely textured, but can be very clearly discerned under moderately low powers, (20 to 25 diameters), of the microscope, as shown by Fig. 3.

When the micropegmatite, still occurring as the dominant constituent of the rock, requires a power of about 50 diameters to resolve its details clearly, the granophyre, although intensely hard and tough enough to rank as a high-grade economic stone, shows signs of passing into the "*Felsitic*" condition. See Fig. 4.

PLATE IV.

Fig. 5.—Spherulitic Felsite, Satavari Jhar, Barda Hills.

Photomicrograph from a Preparation by E. Howard Adye.

Magnified 25 diam.

The field of view in this rock-section, shows a ground-mass of true felsite, studded with a number of spherulites. The felsitic portion consists essentially of a cryptocrystalline intergrowth of quartz and felspar, which, when viewed under ordinary transmitted light shows no signs of structure ; but with polarised light reveals its dual character. The spherulites can be seen to be built up of lighter, (quartz), and darker, (felspar), fibrils radiating from central nuclei, and give the characteristic black cross with polarised light. They are in reality incipient intergrowths of felspar and quartz, foreshadowing the formation of micropegmatite. Spherulitic felsites are always intensely hard, but more or less glassy, and frequently highly ornamental and capable of taking a brilliant polish.

True felsite, in the sense in which the term will hereafter be used in this report, and within the meaning of the name as accepted by progressive petrographers, consists of a massive type of rock, identical in chemical constitution with rocks of plutonic origin, in which the crystallisation of the molten magma has been almost entirely arrested, so as to result in the formation of an apparently homogeneous or *crypto-crystalline* structure, wherein no trace of individuality, as mineral units, can be detected either by the naked-eye or with *ordinary* light under the microscope. The crypto-crystalline or hidden character of the differentiation of the glassy mass into incipient crystals can, however, be made out by the use of *polarised* light; so that if the felsite happens to be identical in chemical composition with a granite, its leading constituents of felspar and quartz can be recognised, in spite of being so intimately and obscurely blended together. Such felsites do not occur naturally, in large uniform masses, but are always more or less diversified by crystalline patches, sporadic crystals or incipient growths.

Felsite and the Felsitic or Crypto-crystalline Structure.

When the crypto-crystalline texture predominates, the rock for all practical purposes may be regarded as a *Felsite*, and in this generalised condition is possessed of physical properties, the principal features of which may be summarised as intense hardness and capability of withstanding severe abrasion; but the texture by reason of its sub-vitreous character, cannot resist sharp blows nor the stress of severe crushing force, and is therefore unsuitable for either general building construction or for road-making operations. On the other hand, the felsites ought to furnish ideal material for the construction of steps, landings and floors,–in slabs and tiles;–and are frequently, in some of their varieties, and altered forms, so highly ornamental, as to justify their use for the production of table-tops, clock-cases, vases, fancy tiles and the like;–as they are all capable of taking a brilliant polish.

Physical Properties and Uses of Felsites.

Transitional phases in the passage of felsites to granophyres are of frequent occurrence among the hypabyssal formations of the Barda Hills. Sometimes, these enormous masses of dyke-rock exhibit variations in texture at different parts, comparable to those so commonly found among acid lava-flows; while among the smaller intrusions of the same (hypabyssal) series, every diversity of geological structure and lithological texture may be discovered, within the compass of even very limited areas; so that in pegging out quarry-sites for the extraction of uniform quality of stone, great care should be exercised to secure material strictly true to sample by quarrymasters who are not also expert petrologists.

Transitional Phases from Felsites to Granophyres.

Although no sharp line of demarcation can be drawn between felsites and granophyres, except in extreme phases of structure, there are, nevertheless, a few practical "wrinkles" that can be made to serve as guides to the student of applied petrology.

Under conditions of very rapid cooling at intermediate (hypabyssal) depths in the earth's crust, an acid magma, would in all probability consolidate to form a *glassy* or *vitreous* rock, more or less crowded with ferro-magnesian microlites and crystallites of indeterminable composition. Such rocks are termed *Pitchstones*; but, although they come within the category of the special series now under consideration, no examples have yet been discovered in Porbandar State.

Pitchstones:—The Glassy or Vitreous Type of Hypabyssal Rocks.

When the same magma takes solid form less rapidly, so that it has time and opportunity, the bulk of the texture instead of being vitreous (amorphous or isotropic), becomes *crypto-crystalline*; that is to say, that while its minor accessory minerals such as iron-ores, and its ferromagnesian constituents, (pyroxene in the Porbandar types), take recognisable form, the dominant portion of the mass consists of an apparently structureless material; but, instead of being isotropic, can be resolved by pola-

Definition of Felsite as an Exclusively Hypabyssal Type.

PLATE V

Fig. 6.—East End of Bridge on the Ranawao Road, spanning the Creek at Porbandar.

Photograph taken, 6th September, 1915, by E. Howard Adye.

A group of "Tchutri" or Umbrella Babuls, *Acacia planifrons*, grows by the side of a site which affords a good exposure, showing a superficial layer of coarse, sandy and much honeycombed Miliolite, overlying thin beds of Consolidated Shell-Sand and Conglomerate of the Dwarka Series or Post-Pliocene Beds; which, in their turn, are found resting conformably upon the upper portion of yellow Limonitic-Limestone of the Gâj Group of Beds of Miocene age.

rised light into birefringent constituents, which exhibit the optical reactions of felspar and quartz so intricately intergrown as to be practically amalgamated and inseparable. To this texture, and this texture alone, when it occurs in hypabyssal rocks, and not when found present in acid rocks of volcanic origin, (as in the rhyolites) the term *Felsite* will herein and hereafter be exclusively applied.

Spherulites and Spherulitic Felsites.

A slightly advanced stage in crystallisation, is heralded by the appearance within the felsitic ground-mass described above, of minute spheres called *spherulites*; and when these are characteristic of the rock-mass, which frequently becomes ornamental, the stone may be called a Spherulitic-Felsite. Under moderately high magnifying powers of the microscope,-from 50 to 150 diameters or so, and with the employment of polarised light, these spherulites may be demonstrated to consist of radially disposed fibrils or elongated crystals (microlites) of felspar and quartz, which are normally, the last minerals to take crystalline form; and, when abundantly present, endow the rock-mass with increased toughness; so that rocks of this description, which are well represented in the Porbandar formations of the Barda Hills, may be utilised not only for ornamental purposes, but the wastage could be profitably broken to guage to furnish good and sound road-metal.

Pseudo-spherulites or closely aggregated Centric Systems of Spherulites.

Subsequent developments of the spherulutic type of structure, may frequently be witnessed among the Porbandar felsites, where the simultaneous crystallisation of the felspar and quartz assumes the form of elongated laths of those minerals projecting radially from a more or less well developed crystalline nucleus, thereby producing so many centric systems; which, when closely aggregated, have by some writers been called *pseudo-spherulites*.

A stage in advance of the above is shown, when further differentiation takes place, and the radially disposed laths of quartz and

felspar assume more highly developed crystalline forms, on an excessively minute scale, thereby giving birth to centric systems of incipient micropegmatite. A rock thus constituted, may confidently be expected to rank as decidedly stronger and tougher than one in which the centric systems or spherulites consist of radially arranged cryptographic intergrowths of felspar and quartz, which can instantly be detected by the use of polarised light under the microscope; for, between crossed nicols they show the characteristic black cross, caused by extinction in those fibres whose axes lie parallel to one of the cross-wires indicating the diagonals of the polariscopic prisms.

Centric Systems of Incipient Micropegmatite.

Incipient micropegmatite, of the character noted above, heralds the type of structure called *granophyric*, which, in its finest development, with reference to the strength of materials, is found forming the ground-mass of rocks properly called *granophyres*; and, among granophyres, it is only those textures that can be very clearly shown to be mainly composed of micropegmatite capable of being most readily studied under magnifying powers of from 20 to 25 diameters, which justify a claim to be placed in the highest grade of building stones and materials, where strength and durability are the criteria upon which to decide.

Granophyric Structure as a Test for Strength in Granophyres.

On scanning the register of rocks collected during the first traverse through the southern and south-western regions of the Barda group of hills, it will be gathered that Porbandar State is exceptionally rich in rocks of the granophyric type, and also contains many felsites of economic worth. These have been very carefully located; but are only provisionally named, pending workshop preparations and laboratory determinations. As soon as this work has been accomplished, each commercially valuable or scientifically interesting specimen will be accurately named and described in detail.

Explanatory matter dealing with the other massive or igneous rocks met with during the surveys up to the end of the first quar-

PLATE VI.

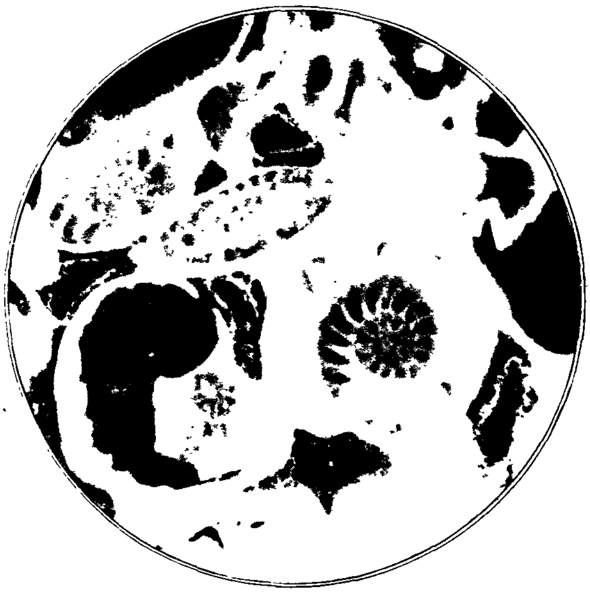


Fig. 7.—Consolidated Shell-Sand, Scarp of Marsania Vokala, Arabian Sea-shore near Lamba.

Photomicrograph from a Preparation by E. Howard Adye. Magnified 20 diameters.

The field of view shows comminuted remains of the shells of *Mollusca*, mixed with a good many well-preserved tests of *Foraminifera*,—*Rotalidæ*, probably of Pleistocene age, bits of other contemporary marine organisms and grains of sand, etc., loosely held together by recrystallised, infiltrated calcite; which however, in this instance, does not fill up all interspaces. This picture has been selected for the sake of comparison, to show, at a glance, the wide difference that subsists between rocks of this type and the true Miliolites of later date.

ter will be given in these pages, as soon as the regions in which they are developed have been traversed. For the present it will be sufficient to note that only one large basaltic dyke in the neighbourhood of Ránáwáo Station, and a small eminence formed by bedded lavas to the immediate E. of Kandorna have yet been encountered.

Basaltic Dyke-rock near Ranawao Station, and Bedded-lava at Kandorna.

With reference to the sedimentary and kindred deposits hitherto identified as forming integral factors or phyla among the rocks encountered during the traverses to date, a brief explanation in this place of their stratigraphical relations, modes of origin, and distinctive features may advantageously be recorded as follows :—

Geological Age of the Massive or Igneous Rocks of Porbandar State.

Evidences of the geological age of the massive rocks, mainly derived from observations in Peninsular-India and also in other parts of the Province of Kâthiáwár, go to prove that the entire series of igneous rocks including the great hypabyssal intrusions, the volcanic dykes and the bedded-lavas, types of all of which are found in Porbandar State, were formed during the Cretaceo-Eocene of the European and the Deccan-Trap Period of the Indian Geological Record.

The convulsions which gave birth to the enormous overflows of lava from gigantic fissures, resulted in the formation of the vast accumulation of bedded lavas with their subsidiary dykes, which to-day constitute the wide plains and ranges of hog-backed hills of the countryside ; and these were clearly consolidated at intervals, probably during the closing of the Cretaceous and the commencement of the Eocene Period ; so that the oldest rocks of the Porbandar State do not date any further back in the history of the formation of the Earth's crust, than the close of the Mesozoic Era.

Volcanic activity, however, was unquestionably rife during early Eocene days, and probably abated and ceased altogether

during that Geological Period ;-its later manifestations being limited to a few violent outbursts through foci of eruption, the wrecks of which, persist in the form of groups of mountains and high-hills, now familiar in our midst as Mount Girnar, and the Barda and Alech Hills.

Early Eocene Age of the Barda Group of Hills.

It is conceivable that the pent-up molten material prior to the final outburst in Eocene times would become differentiated into zones of lighter acid magmas above and heavier basic magmas below; so that when the material was thrust upwards through lines of weakness in the superincumbent solid crust of the earth, the acid and more viscous matter would consolidate practically in the immediate neighbourhood of the outlet; while the more mobile basic matter would subsequently be forced far and wide.

Observations in the field, confirm the assumption noted above; for it has been found that the core of intruded material forming the basal wreck of a huge volcano or compound volcano in the region of the Barda Hills, is composed of denuded dyke rocks of hypabyssal origin, supplemented by contiguous masses and dykes of rhyolite, (acid volcanics), and enormous far-reaching dykes of dolerite, (basic volcanics), which stretch like lofty ramparts from the base of the group to distant parts of the Province.

Upon the cessation of volcanic activity, a prolonged period of severe denudation must naturally have followed to devastate the gigantic mountains to their very base, so as to lay bare their hypabyssal cores; while simultaneous and subsequent earth movements, of the nature of gradual subsidences and elevations of the land must have supervened, to account for the present physiographical features of the countryside.

Detailed studies of the sedimentary deposits along the coastal and sub-coastal areas of Porbandar State, serve to reveal many noteworthy and interesting facts of both scientific and economic significance. It has been found, and duly recorded in the monthly or Narrative Reports of this Department, that there are indisputable evidences to

Miocene Depression of the Land from the Coast of Porbandar to the base of the Barda Group of Hills.

Fig. 8.—Miliolite-Limestone, Adatiana Heights, Barda Hills.

Photomicrograph from a Preparation by E. Howard Adye. Magnified 20 diameters.

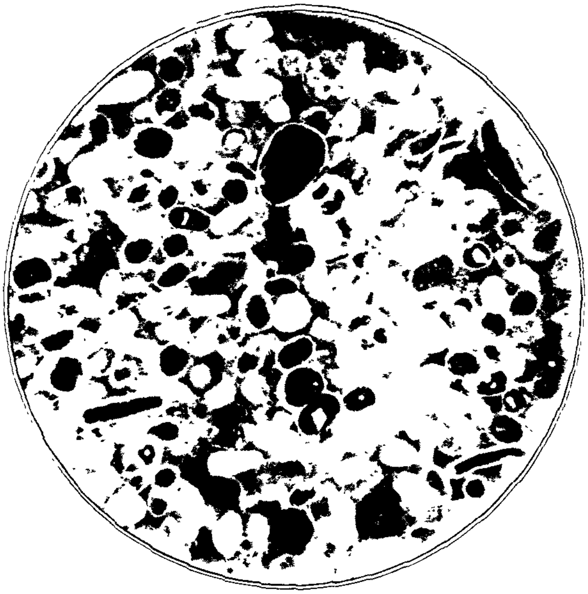
This is a picture of the highest grade of "Porbandar-Stone," to show the practically uniform-size of its clastic particles, firmly held together by a fine mosaic of re-crystallised or secondary calcite. Among the clastic particles there are many tests of pelagic *Foraminifera*, (*Globigerinidæ*), to testify to its origin as a marine sedimentary deposit of probably Pleistocene age. This particular specimen was taken from the central beds of the vast deposit which lies directly upon the hypabyssal rocks eroded to form the exceptionally deep cradle at the base of the south-western flank of the Barda Hills in Porbandar State.

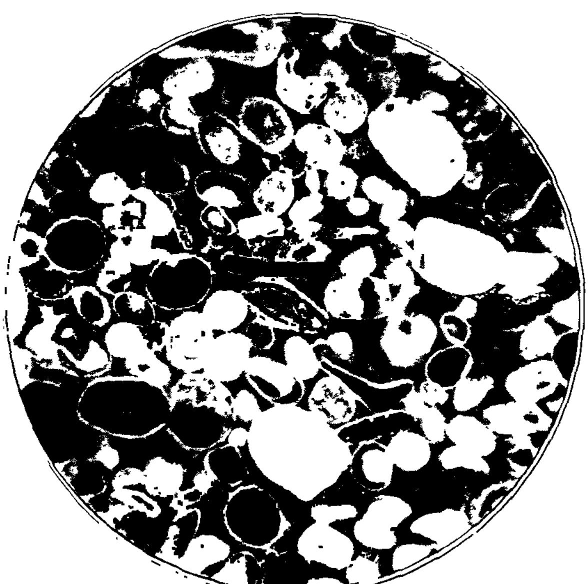
Fig. 9.—Miliolite-Limestone, Amakharda Quarries, Bhanwad, Barda Hills.

Photomicrograph from a Preparation by E. Howard Adye. Magnified 35 diameters.

This picture reveals the fact that the deposit must have been laid upon a site formed of Gaj limonitic limestone, and in the immediate neighbourhood of both hypabyssal and volcanic rocks; for, in addition to the dominant marine organic remains, its clastic constituents include many particles of limonitic limestone, of basalts and traces of granophyres. The re-crystallised matrix of calcite, under this slightly higher power, is clearly shown by the outlines of its *tesseræ*. By reason of the variety of its particles and less uniformity in their sizes, this, although reckoned to be a good building stone, is decidedly inferior to the example shown by Fig. 8.

PLATE VII.





prove that there must have been a gradual sinking of the ground from the present sea-board right up to near the base of the Barda Hills in the direction of Ádatiána and Ránáwáo in the Tertiary Era or more precisely during the Miocene Period,–equivalent to the Gáj Group of Sind and the Dwárka Beds of north-western Káthiáwár.

Limonitic-lime tones and Conglomerates of the Miocene Period or Gaj Beds of Porbandar State.

These deposits consist mainly of limonitic limestones and conglomerates full of characteristic fossils, only just barely detectable in the recently formed rocks of the coast-line, by the rounded fragments imbedded in the latter. The upper beds of these Gáj limestones are also visible at the surface, towards the base of the scarp on the W. bank of the Creek spanned by the bridge of the Ránáwáo Road, Porbandar, and also on the W. side of the N. end of the Victoria Jubilee Bridge, Porbandar. Indications of these Tertiary limonitic limestones also appear intermittently at the surface, according to the sculpture of the land, on the roadsides leading from Porbandar viá Virpur to Ránáwáo, and from Ádatiána viá Kolikhara back to the city. The best development of the stone however, in the vicinity of Porbandar is only to be met with at various depths below the surface; notably by an examination of the well-shaft to the N. of the Dwarkadish Gardens in the Bokhira limit. Exact localities and details concerning these stones have been duly noted in the Register of Samples collected for the State as Nos. 7, 12, 16, 18, 23, 24, 45 [?], 84 [?], 103, 104, and 108.

From former investigations, it is expected that the more extensive deposits of these stones of Tertiary age which are known to occur in still untraversed parts of the State are likely to yield commercial products of permanent importance in the form of ornamental stone in various shades of yellow; and of pigments and distempers of the same colour; which, of course, by the proper application of heat, could be converted into the popular marketable Indian-reds of commerce.

The stone registered as No. 103, occurs as a practically horizontal bed of about 2 feet or so in thickness, at a depth of some 14 to

16 feet from the surface of the ground, disclosed by a newly sunk well-shaft noted above, which lies within the limits of the village of Bokhira, about a mile N. of the city of Porbandar.

Ornamental Pindaralite near the City of Porbandar.

The material appears to be identical with the variety of ornamental limonitic limestone named Pindáralite by the writer; but it would be impossible to state to what extent the stratum is developed, as beds of this character, in the same series of formations elsewhere, have been found to be merely local and apt to vary in texture. Pindáralite, it may be mentioned, occurs as a uniformly textured stone of fine quality, in form of a superficial bed of from 2 to 3 feet in thickness over a very small area in the immediate neighbourhood of the village of Pindára on the SW. shore of the Gulf of Kutch; and is a partially dolomitised limestone composed of almost ultra-microscopic particles indued with limonitic staining, evidently derived from the wearing down of the lateritic rocks adjoining.

This limonitic limestone with its deep substratum of richly fossiliferous and rubbly conglomerates, has been shown to be overlaid by a succession of almost azoic beds, and beds composed almost entirely of comminuted marine shells, *Foraminifera*, and a goodly proportion of sand, and have collectively been assigned by FEDDEN also to the Tertiary Era as the uppermost series of strata of that age, which he designated Dwárka Beds, by reason of differing markedly in lithological characters and fossil contents from the Gáj Beds below, and on account of their typical development in the Okhamandal Taluka.

Consolidated Shell-sands of the Post-Pliocene or Dwarka Beds, underlying the Coastal, (*Pleistocene*), *Miliolite* of Porbandar State.

The beds composed of comminuted shells alluded to above, are found in their lower or conglomeratic layers to contain brecciated as well as rounded fragments of Gáj limonitic limestone; while their upper portions, bear strong evidences of being sub-æolian in origin, or of the nature of raised-beaches. It is these beds that are found exposed all along the coast-line in the vicinity of Porbandar-city, and which stretch far inland to even appear intermittently

PLATE VIII.

Fig. 10.—Large Sub-vertically jointed Blocks of Rhyolite, exposed by the Erosion of the Orio Vokala, 500 yards W. by WNW. of Nágka. From a *Photograph* by E. HOWARD ADYE, F.G.S., taken on the 7th December, 1915. The large size of the blocks may be gauged by comparison with the youth at the right-hand side of the picture. The stone has been weathered and sunbaked to a fine fawn colour; and, as such, is distinctly ornamental; but deeper down, where it is unaltered, assumes a fresh, greyish hue. It is of dense, finely-grained, practically homogeneous texture, with very small whitish porphyritic crystals of felspar; and is capable of being easily tooled into building-blocks of ordinary sizes, and of taking a good polish. The site shown by the photograph indicates the central portion of a large dyke, and affords a good 'back' for commencing quarrying operations.

at the base of the Bardas. The lower strata of these Dwarka Beds do not appear to be represented in the Porbandar State; but in the Okhamandal Taluka where they comprise tolerably thick deposits of ochreous earthy rocks, calcareous clays and gypseous deposits, conformably overlying the Gáj or Miocene deposits, they unquestionably belong to the Higher Tertiary or Pliocene Period; while the overlying beds of foraminiferal and molluscan shell-sand which tail off lenticularly to the SE., or Porbandarwards, are probably of Post-Pliocene, if not distinctly of Pleistocene age.

Elevation of the land, in Post-Tertiary times, and the subaerial denudation which followed, would be sufficient to account for the comparatively poor representation of the Tertiary Gáj and Dwarka Beds along the W., SW., and S. shores of Káthiáwár; but it is certain, that a prolonged period of subsidence, probably commencing in early Post-Pliocene days, with the accumulation of the Upper Dwárka Beds, must have continued far on into the Pleistocene Period, causing marine deposits to be gradually showered down, at first upon the littoral of the sea, but afterwards, as the subsidence went on, upon all previously formed submerged ground, until nothing remained of the former land but a few islands, to represent the summits and slopes of only the highest hills and mountain tops of Káthiáwár. The final elevation of the entire Province, with periodic states of quiescence, and of extensive denudation, would suffice to account for the present geological structure of the land, as follows:—

Age, Origin, Structure and mode of Occurrence of the Miliolite Deposits of Porbandar State.

The Consolidated Shell Sand, so freely found forming a substratum, overlying the Gáj limonitic limestone, in and around the City of Porbandar, tails off gradually towards the elevated base of the Barda Hills; but is found to be covered by deposits of quite a different character of stone, now familiarly known by the name of *Miliolite.* This miliolite occurs overlying all previously existing rocks;-but only up to a definite limit upon the hill-slopes. The base of the miliolite is frequently of the nature of a conglomerate, and is often false-

bedded; thereby proclaiming deposition in littoral depths, under more or less turbulent conditions. Its layers immediately above the conglomeratic portion, are usually much cancellated, and its texture coarse and sandy; both of which are signs of sedimentation in the "Laminarian," or zone of great growths of *Algæ*. If the deposit is very thick, the overlying layers are found to be increasingly uniform, free from deficiencies, and composed of the tests of pelagic as well as bottom-dwelling *Foraminifera*. Now, upon the elevation of the land, the total deposit would continue to increase,- but in an inverse order to the above, namely:—The finest quality of stone would grow gradually coarser, then become cancellated or honeycombed, and finally conglomeratic and obliquely laminated. Breaks in the continuity of elevation, or very gradual elevation, would serve to add fragments of already formed miliolite, that had risen above the sea level, to the material in progress of formation in both the shallows and the depths of the sea; so that by subsidence and elevation, coupled with the modifying influences of sub-aerial denudation and changes due to percolation, solution and re-deposition, a series of terraces of different textures of stone, which would necessarily vary both vertically and horizontally, would naturally result; and that is exactly what has been found to be the case in tracing the superposition of the strata from the sea-level at Porbandar to its maximal development on the heights of Ádatiána.

Sub-recent and Recent Rocks of Porbandar State.

Since the deposition of the miliolite during the Pleistocene Period, there does not appear to have been any subsidence of the land; but, on the contrary there are signs that the elevation has been and is still going on. In consequence of this, new rocks are being added to the surface of the land mainly in two ways. Firstly, by detritus washed down from elevations to mingle with the disintegrating surface rocks below, or to be carried by watercourses to the sea; and secondly by æolian deposits, raised-beaches and river-terraces, all of which may be included under the headings of Sub-recent and Recent rocks, and many of

PLATE IX.

Fig. 11.—**Vein of Black Obsidian intercalated with Bands of Lithoidal Rhyolite.** Contorted by being thrust through a Fissure with sundry obstructions. ESE. Scarp of Nala to Orio Vokala, 350 yards WNW. of Nágka. From a *Photograph* by E. HOWARD ADYE, F.G.S., taken on the 7th December, 1915. **O.** Obsidian. **L.** Indurated, Lithoidal Rhyolite intercalated with the Obsidian. **R.**—Lithoidal Rhyolite underlying the Obsidian-vein. **C.**—Contorted portion of the Vein.

which will be enumerated and described in the sequel among the economic stones of the State.

From the explanations afforded above, concerning the leading types of stone met with during this first traverse of the State, their origin, and relative positions upon the geological record, the following summary of facts and conclusions will now be more readily understood and duly appreciated :—

Summary of Results of the First Geological Traverse of Porbandar State.

The area of the State covered during the first traverse, may be roughly indicated as being included within a circumscribing line (see Map) from Porbandar City through Khápat, Kolikhará, Ádatiána, the extensive miliolite quarry-sites and adjoining granophyre grounds on the Ádatiána-Ránáwáo heights, Ránáwáo Railway Station, the Ránáwáo State-Jungle Reserve, the country to the south of the Railway-line as far as Bordi and beyond to the State-boundary, the State-boundary to the South of the Railway-line as far as the town of Kandorna, and the countryside north of and immediately surrounding the main-road from Kandorna viá Wadwála, Ránáwáo-town, Virpur and back to Porbandar Geological Survey Headquarters. The sea-coast and its borderland from Porbandar Customs-house to a little beyond the Ráná Saheb's Palace, was also carefully traversed.

The Earlier Eruptives or Bedded-Lavas of the Deccan-Trap Period.

The oldest rocks encountered, belong to the Cretaceo-Eocene Period of the European Geological Record which is substantially equivalent to the Deccan-Trap Period of Peninsular-India. Among the earliest formed rocks of this period, represented by the Bedded-lavas and their dykes, only a very limited area is exposed to the E. of the River Minsar, but is obscured by their denuded deposits of coarse miliolite. Only one hog-backed hill of bedded-basalt, called Dhanak Dhár, just E. of Kandorna remains uncovered; while the miliolite-conglomerate forming portions of the western scarped banks of the River Minsar at Walotra, but also at Khirasra, Kandorna and

Khijdar is full of brecciated as well as rounded fragments and pebbles of amygdaloidal and compact basalts manifestly derived from the underlying bedded-lavas. In the map the bedded-lava areas are tinted green, while the short parallel blue lines over the green ground show where the volcanic rocks are covered by deposits of miliolite.

The Later Eruptives or Hypabyssal and other Dyke-rocks of the Deccan-Trap Period.

The later eruptive rocks of the Deccan-Trap Period, which, as already noted, probably consolidated at the beginning of the Eocene epoch, mainly in the form of hypabyssal intrusions, as well as acid and basic volcanic dyke-rocks, constitute, perhaps, the most important asset in economic stone that yet remains undeveloped. They include, among the hypabyssal members, a magnificent series of granophyres, which show every phase in the development of micropegmatitic structure ;—sure signs of great strength in the texture. On the map, the granophyres, and granophyric-felsites occupy sites coloured green with small red crosses, and where this is limned over with short-blue parallel lines, it indicates that the granophyres are overlaid by a deposit of miliolite. The felsitic or cryptocrystalline phase, is in like manner shown by a green ground with red dots, and parallel blue lines to show the presence of miliolite deposits. Red crosses mixed with red dots on a green ground are used to denote intermediate phases, typified by granophyric felsites, and spherulitic felsites.

Conventional Colours and Signs on the Geological Chart of Porbandar State.

All of these hypabyssal rocks, namely the typical felsites and granophyres and their intermediate varieties constitute the vast bulk of the Barda group of hills, with their great spurs, and far-stretching outliers, the latter of which by reason of their accessible positions, offer exceptionally favourable sites for the opening of quarries. Quarry sites, capable of being profitably worked are marked on the map by small circles inclosing the registered number of the particular kind of stone there to be found.

PLATE X.

Fig. 12. False-bedded Miliolite-base Resting directly upon the Denuded Surface of the Mountain=massive. Railway-cutting about ½ mile E.N.E. of Rináwio Station. From a *Photograph* taken by E. HOWARD ADYE, F.G.S., from a distance of 10 feet, on 27th October, 1915, at 12-50 p.m. Glints of sunlight are shown falling *upon projections from the structure.* **M.**—*Section through false-bedded miliolite.* **S.**—Blasted spheroidal nuclei of vertical columns of the mountain-massive.

Only one example of a basic volcanic dyke rock belonging to the later or closing days of eruption of the Deccan-Traps, has as yet been identified forming the very considerable nether hill ENE. of Ránáwáo Railway-Station ; and is indicated on the map by hatched red-lines.

The Tertiary rocks are shown upon the map by orange-coloured patches to point to the presence either near the surface or as outcrops of Upper Miocene beds of marine and fluvio-marine origin, which correspond in part with the fossiliferous limonitic limestones of the Gáj Group of Sind, and the lower portion of the Manchhar Group of Sind respectively ; while the Higher Tertiary (Pliocene) and probably the Lower Quaternary (Pleistocene) or Glacial Period deposits, defined by FEDDEN as the Dwárka Group of Káthiáwár, is rendered yellow on the chart. Wherever these rocks are obscured by deposits of miliolite, the orange or yellow grounds are lined with blue.

Lastly, all Recent or Sub-recent deposits are indicated on the map as follows :—Raw-umber for alluvial lands, river-terraces and recent conglomerates. Raw-umber with red dots, for blown-sand (dunes) and sea-shore sands. Raw-umber with red lines, for raised-beaches and consolidated shell-sands of probably Pleistocene age.

Rocks of economic importance or deposits of agricultural interest are localised on the map by small circles with the registered numbers of samples collected, for details concerning which, reference to the list of samples should be made.

DAMODARDAS PRINTING HOUSE.—RAJKOT C. S.

PLATE XI.

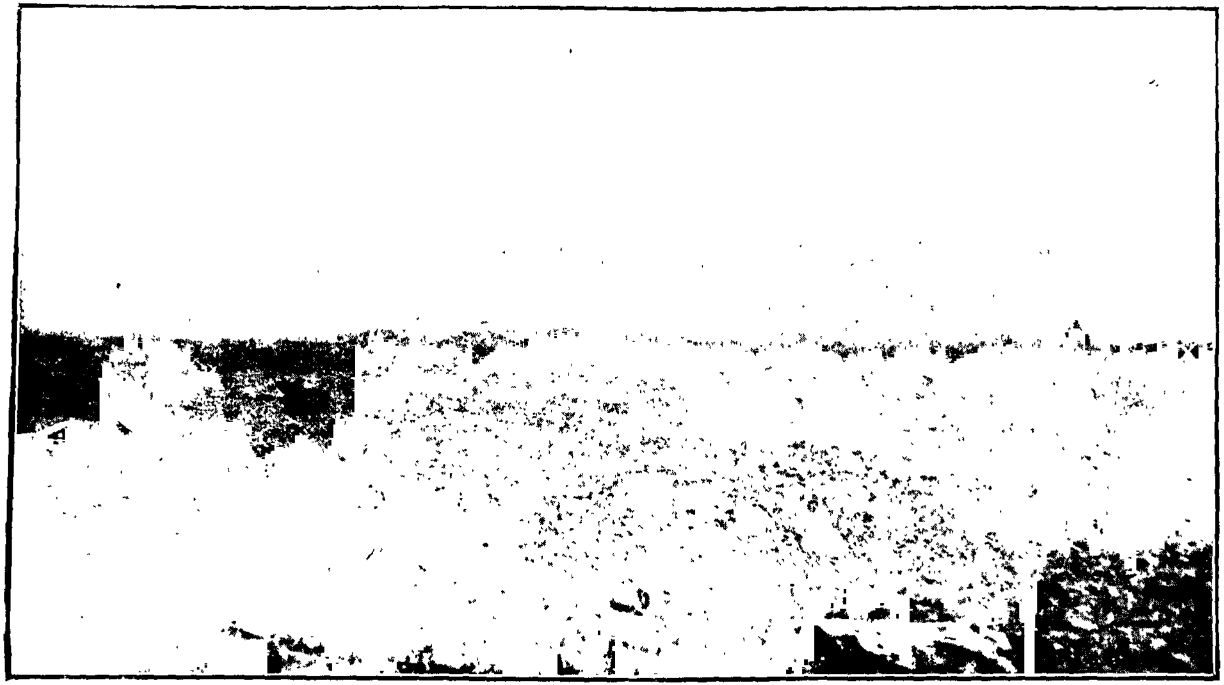


Fig. 13.—The Limestone-limit, Ádatiána Heights, Barda Hills, Porbandar State.—Viewed from the NE. side of Ádatiána Village, approximately *one mile from* the extensive line of Quarries,—**X** to **X**, 300 feet above the mean sea-level. From a *Photograph* taken by E. HOWARD ADYE, F.G.S., 22nd October, 1915.

SECOND QUARTERLY REPORT

ON

THE ECONOMIC GEOLOGY OF PORBANDAR STATE

BY

E. HOWARD ADYE, F.G.S., ETC.,

Director, Geological Survey of Porbandar State.

September to November 1915.

SINCE THE COMMUNICATION of the First Quarterly Report, geological reconnaissance work with special reference to the applied petrography of the State, was continued northward from a base-line, extending roughly from Porbandar City via Ádatiána to the foot and nether eminences of the Barda Hills, as far as the boundary of Vandhra Jhár on the east, to the town of Khámbhodar at the west.

During these traverses, a couple of new types of rock were met with, which call for comment in this place, as they are represented on the geological chart, now in course of preparation, by conventional colours not hitherto noted. These rocks are respectively the " laterites " and the " rhyolites";-the former being shown on the map by patches of burnt-sienna and the latter by thin red lines, in short parallels, from NW. to SE., on a green ground.

Etymologically, the name laterite is derived from the Latin word *later*,-a brick; by reason of the characteristic brick-red colour of the material. Its resemblance to its prototype, goes still further,

Definition of Laterite, and Laterisation.

for it is usually hard and even slaggy and generally cellular in texture and structure. This definition holds true, in substance and in fact, for the bulk of the laterite as it obtains in

Porbandar State. In its perfectly fresh, undecomposed, condition, the laterite shows scoriaceous zones, passing insensibly into densely compact layers; with indications of joints, spheroidal shrinkages, veins of fissure and of intrusion; all in exact counterpart with the phenomena to be observed in connection with the bedded-lavas of the Deccan-Trap Period.

Varieties of Laterite.

Laterite of a different kind, also occurs among bedded-lavas separating one stratum from another. At times, the dark-red material is only an inch or two in thickness, and generally quite hard and even vitreous; at others, these bands are several feet in thickness, and tolerably soft. These varieties of laterite have been shown to be nothing more nor less than burnt layers of soil or of volcanic dust, transformed by the passage over them of molten matter. When the decayed surface of one bed of lava is very thin, the flow of a succeeding sheet, would naturally fuse that superficial layer into a hard brick-like lamina, and a thin vein-like zone of sub-vitreous laterite with an intimate, (microscopic), structure, closely resembling that of brick or red-earthenware, would result. On the other hand, when a considerable period of time has elapsed, sufficient to decompose the surface of a lava-bed into a fairly deep layer of soil, more or less saturated with meteoric water, and is then subjected to intense sudden heat from the overflow of a second sheet of lava, the sodden soil would likewise be converted into laterite; but of a comparatively soft consistency. It is doubtless in this way that the kind of lateritic substance called "bole" is formed. A variety of bole richly stained with ferric hydrate, or of degradation products in an earthy condition derived from laterite or other rocks and similarly coloured, furnishes the basis of the red-ochre of commerce,-otherwise rich-red, earthy hæmatite.

Incipient Laterite.

Laterisation in an incipient condition may be observed in rocks of every description that have undergone intense sunbaking and monsoon conditions alternately for prolonged periods;-as in most moist and tropical climes. The hardening and changes of colour mostly due to the oxidation of the contained iron, in the superficial and some-

PLATE XII.

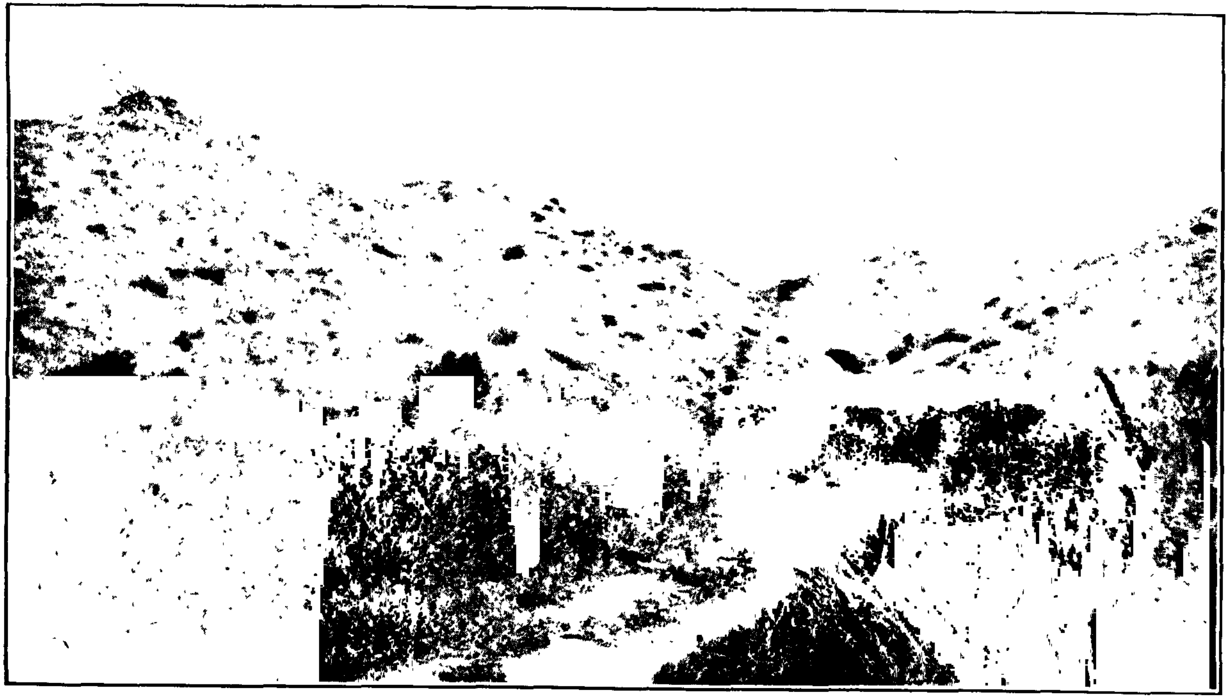


Fig. 14.—"Bhil Jhár," a Gorge in the Barda Hills of Porbandar State. To point the pathway leading over the hills to the vale of Sathvirda, and to exhibit the typical physiographical features of hypabyssal formations. From a *Photograph* taken by E. HOWARD ADYE, F.G.S., 24th October, 1915. **F.**—Nether hill of Felsite. **G.**—Hill-spur of Granophyre.

times in the deeper portions of igneous as well as sedimentary or aqueous rocks, whereby many varieties of fawn-coloured, brown, red and purple ornamental stones of commercial value are yielded from originally grey and black or blue-black textures, ought to be familiar to the most casual observer; and are all primarily due to the effects of laterisation arrested at an early stage. These may be witnessed in almost every type of rock gathered for the State collection;–details of which will be recorded in the sequel, as soon as the laboratory determinations of samples can be completed.

Metachemic changes, resulting in a complete alteration of the rock-mass into the substance technically termed "laterite," are most noticeable in connection with the bedded-lava formations of the State, on approaching its northerly coastal regions. The laterite, originally in the form of rust-coloured caps to the hog-backed hill-ridges, which trend from the NW. to the SE., intermittently, have often been denuded so severely, that their remains are sometimes coincident with or below the level of the surrounding plains,–as at the south of Ránáwáo; or in long low elevations to the immediate W. of Bákharla. The subaerial decomposition of the lavas exhibits a pisolitic structure at places,–doubtless the vestiges of former amygdales in the scoriaceous zone of the lava bed; while the subjacent compact, much-jointed laterite, corresponds of course, with the compact or central body of the lava. In the joints and fissures pervading the mass, thin and thick separations of good iron-ore have accumulated. Further decay, gives birth to the production of aluminous and ferromagnesian silicates and of disseminated lime; but recent researches have shown that most of the silica, alkalies and alkaline earths are washed away by meteoric waters, leaving behind a hydrate of alumina stained with ferric hydrate, and mixed with impurities liberated by the weathering and wearing-down of the rock.

Laterite in Porbandar State.

Another kind of laterite, noticeable at Bákharla, consists principally of a soft, earthy, dull-red rock, sometimes hardened by nodules of iron-ore, which it would be difficult to account for, except by a close observation of the overlying strata. The laterite substra-

tum, in this case, probably fully formed in early Eocene, or, at all events, Pre-Miocene times; was subsequently overlaid by Gaj (Miocene) or Dwárka (Pliocene) beds, in the form of a conglomerate composed largely of pebbles and fragments from the laterite; and this, in its turn, capped by compact limestones of Tertiary age which were denuded down to almost vanishing point, was overlaid, in Pleistocene days, by a deposit of miliolite;—of which only traces now remain. The re-exposed conglomerate of laterite-pebbles, supercharged with infiltered lime, must next have been indued with diffused ferric hydrate stain, and the whole finally sunbaked and alternately water-soaked, to produce a highly-calcareous dull-red laterite. When the laterite pebbles remain practically unchanged, and the authigenous lime is recrystallised between them to form a compact texture, an exceedingly beautiful stone, resembling a red granite, results, to which the writer has given the name "Habardilite", from its having been first found and utilised, in the neighbourhood of Habardi in Western Navánagar.

Ornamental Stones derived from Laterite.

Habardilite, the original variety of ornamental stone derived directly from laterite, and described and figured by the writer in his "Memoir on the Economic Geology of Navánagar State,"* as a laterite-conglomerate, easily tooled and capable of being polished, has clearly been shown to originate by the deposition of beds of miliolite-limestone, probably during the Pleistocene Age, upon a substratum of depressed and disintegrating laterite.

In other regions, where the already formed laterite was fast subsiding in a Tertiary sea, and covered by deposits of limonitic-limestone, the pebbles and fragments of the underlying laterite, would similarly be cemented together by limonitic-lime; and, upon its subsequent elevation and consolidation, would naturally yield laterite-conglomerates and breccias of a distinctive character dependent upon the nature of its binding matrix.

Material of the abovenoted description was found to be present in tolerably large development in the neighbourhood of Tukra on

* pp. 204-206. Plate XXXII.

PLATE XIII.

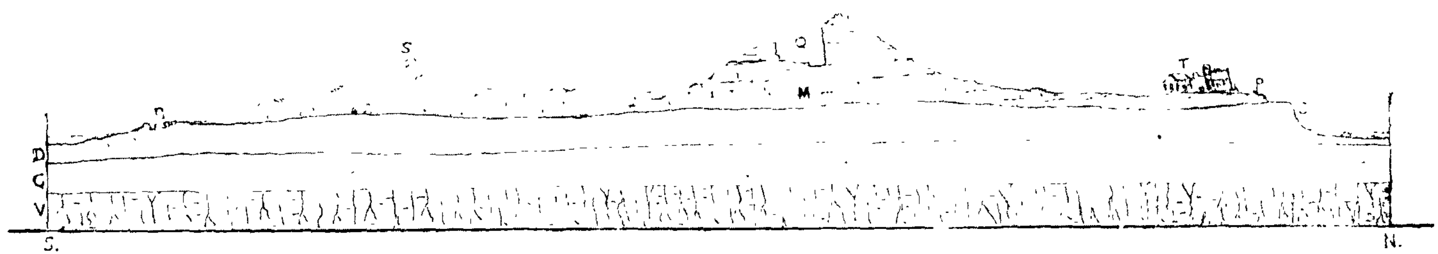


Fig. 15.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland from S. to N. through the Neighbourhood of Miani. V.—Volcanic rocks or Bedded-lavas of the Deccan-trap Period. **G.**—Limonitic-limestones or Gáj, (Miocene), Group of Beds. **D.**—Dwárka, (Plio Pleistocene), Group of Beds, showing 'Breakers' at **B.**, and the Coral-reef at **C.** The town of Miáni, **T.**, is shown resting upon Basal-beds, **M.**, of Miliolite of Pleistocene Age. **P.**—Level Datum Pillar. **Q.**—Quarry in the Miliolite at the S. side of the town. **S.**—Sand-dunes overlying the Dwárka Beds and overlapping the Miliolite.

the Porbandar State coast, and has therefore been designated *Tukralite*, in anticipation of its being found, when properly prospected, to yield sound ornamental stone in sufficient quantity to justify its being placed upon the market. Tukralite may therefore be correctly assigned to the Miocene Age.

Other ornamental stones indirectly due to the presence of laterite, are also found in small local development in various situations overlying the coastal and sub-coastal caps of laterite in Porbandar State. These are mainly of the nature of laterised pisolites and pseudo-oolites, sometimes of extreme beauty and sufficiently compact and indurated to take a good polish ; but have hitherto been only found in a fragmentary condition, capable however of being utilised for the production of small ornaments such as vases, clock-cases, paper-weights, etc. There can be no doubt that these stones are simply organic limestones heavily stained by the iron from the laterite upon which they were deposited. Coarse pisolitic-laterite as it may be called, occurs in tolerably large broken blocks, on the summit of a hillock ½ mile NNW. of Tukra, and is evidently a laterised, Tertiary, fossiliferous limestone ; while the pseudo-oolitic laterites, are in the same way, nothing more nor less than laterised miliolite-limestones.

Origin of Laterite.

From the foregoing observations, it may be gathered that the name "laterite" has been well-chosen to signify simply burnt or baked mineral-matter, often in the presence of moisture ; but more frequently by the analogous processes of alternate intense sunbaking and monsoon conditions. This inference however, is insufficient to account for the peculiarly limited areas in which the main masses of laterite are found ; namely, as caps along definitely restricted ridges or isolated areas ; while precisely similar rocks adjoining, remain unchanged.

To account for this apparent anomaly, many persons are content to simply call it a "freak of nature"; while others, more philosophically inclined, attribute the change properly called "laterisation," to metasomatism caused by some yet undiscovered germ or

other organism, which, by living and thriving on the rock, possesses the power of breaking up its silicates in such a way that the silica can be carried away by percolating waters; while the hydrated alumina and oxide of iron segregate, to cement all other products of decomposition or partially altered particles into the cellular red and mottled-mass familiarly called "laterite."

Special and Subordinate Uses of Laterite.

The segregation of the iron oxide, usually manifests itself in the form of superficial crusts, sometimes of considerable thickness, and these are mostly found continuous with secondary vein-like separations and subsidiary veinlets of more or less pure hæmatite, which run along the fissures of former joints, and cracks therefrom; so that the entire mass may be eventually involved in a meshwork of iron-ore.

Iron-ore from Laterite.

It thus "falls out," that laterite may become the seat of rich developments of hæmatitic iron-ore of excellent quality; and one fairly good locality, known to this day as the "Iron-mines site", to the immediate W. of the village of Bákharla, was formerly, (about a century ago), a flourishing centre of the iron-smelting industry in Porbandar State. These so-called "iron-mines," consisted in a number of small pits of from 4 to 6 feet in diameter, dug haphazard into the superficial laterised conglomerate and the underlying massive laterite, to depths rarely exceeding 10 or 12 feet. When the industry was abandoned some seventy years or more ago, on account of the cheapness of imported iron, the pits were desultorily filled in with rubbish by the villagers, presumably to prevent accidents to straying cattle; or, as likely as not, to close the shelters thus afforded, against the undesirable vermin,–jackals, porcupines, mongooses and snakes,--in which the countryside unfortunately abounds.

It is not at all probable that the defunct iron industry, at the Bákharla site at all events, will at any future time be revived; although it is commonly rumoured that the smeltings yielded a better quality of iron than the present supply of imported metal. There are other sites, however, belonging to the great lateritic belt, of

PLATE XIV.

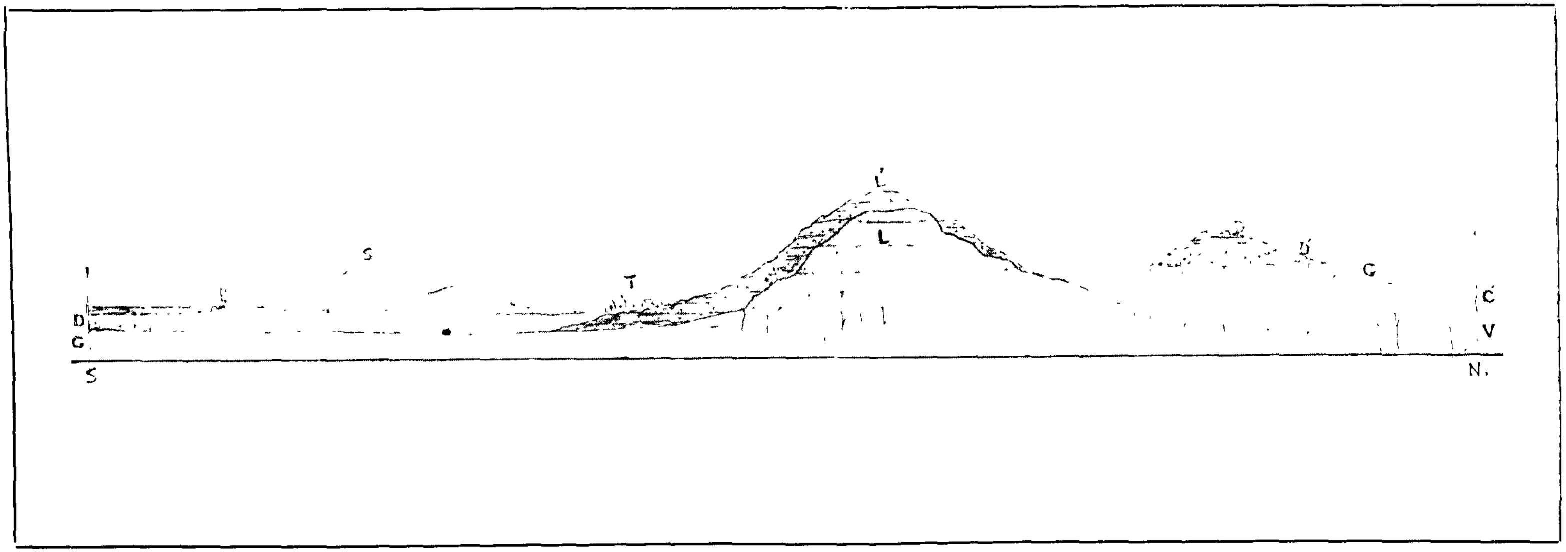


Fig. 16.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland through the Parallel of Tukra. **V.**—Volcanic rocks or Bedded-lavas of the Deccan-trap Period. **G.**—Gáj, (Miocene), Group of Beds. On the right-hand side these are shown differentiated into **G′.**—*Fossiliferous* Conglomerate and **G.**—Compact Limonitic-limestone of the 'Pindáralite' type. **D.**—Dwárka, (Plio-Pleistocene), Group of Beds. On the right-hand side these are exposed as **D′.**—Fossiliferous Conglomerate, overlaid by **D.**—Apparently Azoic Limestone. **B.** 'Breakers' of Dwárka Sandy and Shelly Limestone at lowtide mark. **L.**—Lateritic-cap forming a hillock on N. side of the village, **T,** of Tukra. **L′.**—Laterised Organic-limestones and Conglomerate called 'Tukralite.' **S.**—Sand-dunes.

which the Bákharla site is but a small outlier, where the ore occurs in such profusion, that it would doubtless be commercially possible to erect a few small blast-furnaces and keep them profitably active.

Alum and Aluminium from Laterite.

The interspaces between the meshes of separated iron-ore noted above, are commonly filled with impure segregations of whitish alumina hydrate; which, however, as frequently become stained more or less heavily with ferric hydrate. This material appears to be closely related to, if not identical with the substance called "Bauxite," which was discovered and originally utilised at Baux-pres-Arles, in the south of France, for the manufacture of alum and aluminium on a commercial scale. It does not occur in either sufficient quantity or purity in the neighbourhood of Bákharla: but there is nevertheless a tolerably large development thereabouts of a soft dull-red laterite, clearly shown by gradual transitional forms to be derived directly from the superjacent beds of limestone-conglomerate originally crowded with laterite pebbles and fragments, which has become so heavily indued with ferric hydrate, and holds such a large proportion of decomposed pellets of hydrated alumina, as to furnish a goodly supply of refractory material, which it is suggested, might be turned to good account for lining furnaces.

Impure Laterite suggested as suitable for Lining Furnaces.

The segregative power of the hydrates of alumina and iron in laterite has served to endow the material with physical properties which have been taken advantage of by engineers and others, in localities where road-metal of good quality is scarce. It was found that when lumps of laterite are wetted, laid and compressed by rollers, they speedily unite to form a firm, level and resilient surface, in every way adapted for ordinary roadways that are not subjected to severe and heavy traffic. If properly drained, such roadways, by reason of the porosity of the laterite top-dressing, can be kept comparatively free from slush during wet-weather; but when the

Minor Uses of Laterite.

dry-season sets in, and high winds prevail, the clouds of red-dust from such roadways, have only too often been vetoed as an unmitigated nuisance. Laterite however, has found favour elsewhere for the building of culverts; but, by reason of its otherwise desirable attribute of porosity, and the excess of iron which it bears, can be but of little if any use to the agriculturist or rural economist. This is strikingly borne out by the paucity of natural vegetation, and the stunted shrubs and trees found in lateritic regions.

In a country so rich in building-stones as Porbandar State, the lateritic rocks are not likely to be utilised even locally, except for the erection of piled-up stone-walls; but it may be noted, in passing, that on the Malabar coast and in the island of Ceylon, laterite is largely used for the building of dwellings. In this connection MR. JOHN WATSON of Cambridge records,* that :—"When first quarried the rock is so soft that it can easily be cut out with a pick, sometimes even with a spade; but it hardens greatly on exposure. When the stone is sufficiently hardened after being quarried, it is then chipped or chiselled into shape and used for building. It seldom attains a hardness which will enable it to resist the decaying influences of the weather, so it is usually covered with plaster or mortar as a protection. In the coastal districts, however, many temples, some of considerable antiquity, are built solely of laterite, and appear to have stood well." Concerning Ceylon, he further notes:- " Many native houses on the island are built of this material.When protected from the weather by a coating of mortar, which is usually composed of two parts of sand to one part of coral lime, these buildings prove to be very serviceable."

The Rhyolites of Porbandar State.

Turning now briefly to the second commodity of economic importance noted above ;-namely, the Rhyolites of Porbandar State,- the following observations may be taken as fairly exhaustive of the subject; as this particular type of rock appears to be strictly limited to a few low-lying dyke ridges, bordering, at a distance of 1½ miles, the extreme western base of the Barda group of hills.

*" British and Foreign Building Stones," Cambridge University Press, 1911, pp. 240-242.

PLATE XV.

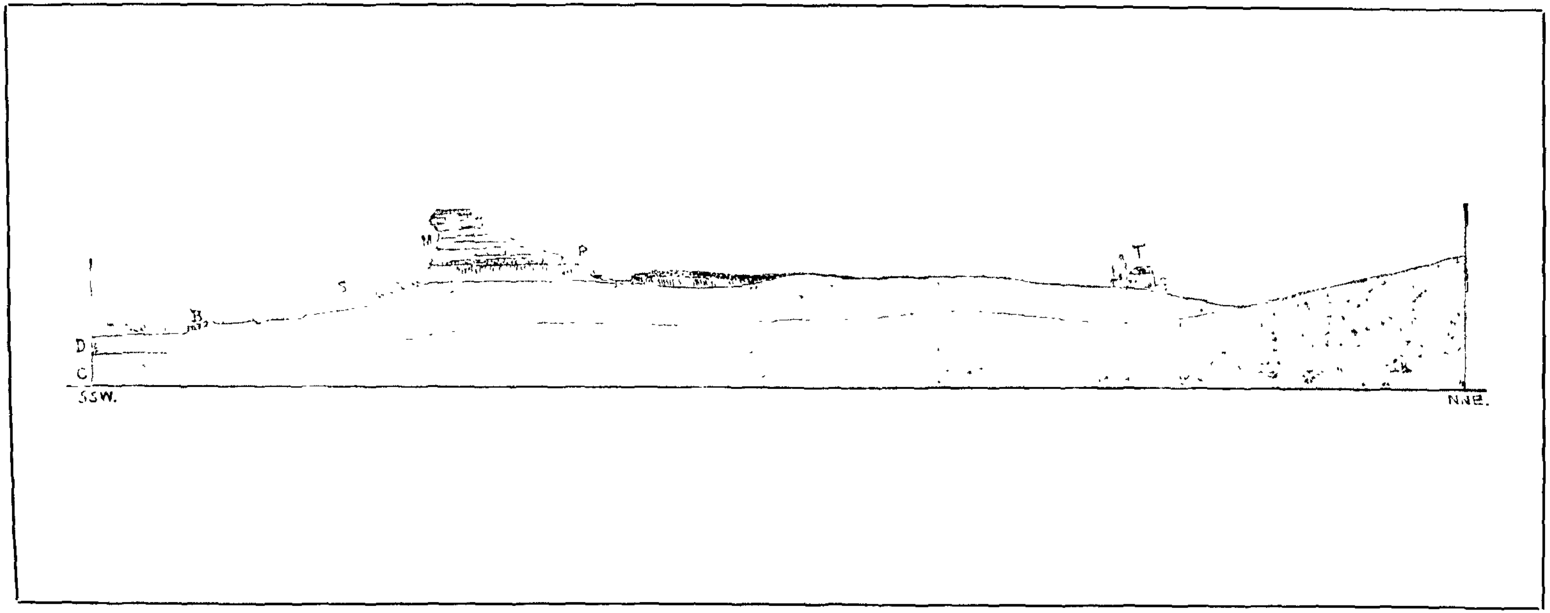


Fig. 17.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland SSW. to NNE. through the Parallel of Visawara. **G.**—Gáj (Miocene) Group of Beds. On the right-hand side, where these are exposed, immediately NNE. of the town and its adjoining *talav*, the limonitic-limestone is conglomeratic and richly fossiliferous. **D.**- Dwárka (Plio-Pleistocene) Group of Beds, exposed at **B,** low-tide mark, as breakers, and forming a coral-reef scarp **C.,** at the creek-mouth. **R.**—Gravelly river-terrace of early Pleistocene Age. **M.**—Miliolite. **S.**- Sandy stretch of beach.

The dykes trend practically N. and S. for a distance of nearly two miles above ground from the N. of Khistri to the W. of the village of Nágka; and exhibit sundry diverticula from ESE. to WNW., the principal of which stretches from a point 3 furlongs SW. of Nágka, for a distance of about 3 furlongs WNW. to vanish and then reappear on a level with the ground, about a mile farther WNW., in Navánagar territory. This diverticulum, appears to be differentiated at places into vitreous bands of obsidian of a black and sometimes brownish colour *en masse*, as shown by detached fragments here and there that have found their way to the surface; and, it may be noted, in this connection, that an essentially similar dyke belonging to this formation, is exposed; with a typically-formed, wide band of black obsidian immediately NNE. of the village of Rojhra in Navánagar State, which lies only 1¼ mile to the W. of the middle portion of the main N. and S. rhyolitic intrusion. The glassy bands of obsidian are found to occur alternating with the commonly lithoidal rock in the same lava-flow; while at the edges of the intrusive mass more particularly, and where the rock is subjected to contact metamorphism by the subsequent intrusion of basic dykes, the texture becomes indurated and frequently, closely banded.

Occurrence of Obsidian.

With special reference to the occurrence of obsidian in Porbandar State, the following extract from the writer's reconnaissance notes, may here be incorporated with advantage:—"While tracking the northward course of the main rhyolitic dyke from ½ mile WSW. of Nágka to its apparent termination 500 yards W. by WNW. of th age, it was noticed that the stray fragments of obsidian were with, amid the superficial shingle of the dyke, more frequent ad it was therefore expected that an outcrop thereof would s be detected. In swerving slightly eastward, the dyke is eroded to its very centre by the channel of the Orio Vokala, and affords thereby an exceptionally good view of its subvertical columnar jointing;—of which a photograph, Fig. 10, was

Exceptionally fine Exposure of Obsidian near Nagka.

taken. It is thereafter obscured by a deep layer of soil; but manifestly narrows down, to be re-exposed in a remarkable manner by the erosion of a tributary *nâlà* to the Orio Vokala, some 350 yards WNW. of Nágka. At this part, which is evidently the termination or forked termination of the dyke, the banded character of the rhyolite becomes extremely perfect, being differentiated into zones of fissile, black obsidian intercalated with much jointed slabs of highly indurated lithoidal rhyolite;–the entire mass being characteristically contorted by its flow, and adapting itself to the sinuosities of the fissure through which it was forced, as shown by the photograph, Fig. 11.

It is more than pro bable that the rhyolite dykes of Porbandar State, located above, emerge farther westward to spread out into beds or sheets of lava; as it has been found and recorded by the writer,* that the WNW. diverticle from the N. & S. dyke, about ½ mile SW. of Nágka, runs aboveground, for fully three furlongs, to vanish, and then reappear on a level with the land, midway between Háthla and Rojhra in Navánagar State. The rhyolite at this part is of a ruddy-brown colour and rough trachytoid texture, exhibiting marked flow-structure at places and pervaded, after the fashion of basic bedded-lavas, with columnar joints and spheroidal shrinkages.

Definition of the Name "Rhyolite."

When molten mineral matter consolidates upon or near the surface of the earth, that is, by more or less rapid cooling and under conditions of comparatively low pressure, the resulting rocks, whether of the nature of extruded lava-flows, or intrusive sheets, dykes, etc., are classified by petrologists as of *Volcanic* or *Eruptive* in contradistinction to the more deeply seated *Hypabyssal* rocks already treated of, and the Abyssal or *Plutonic* rocks of holocrystalline texture formed at considerable depths within the earth's crust.

Volcanic rocks, moreover, are, for the sake of coventional description, separated into several *groups* by reason of predominat-

* "Memoir, Economic Geology of Navanagar State," Bombay, 1914, p. 42.

PLATE XVI.

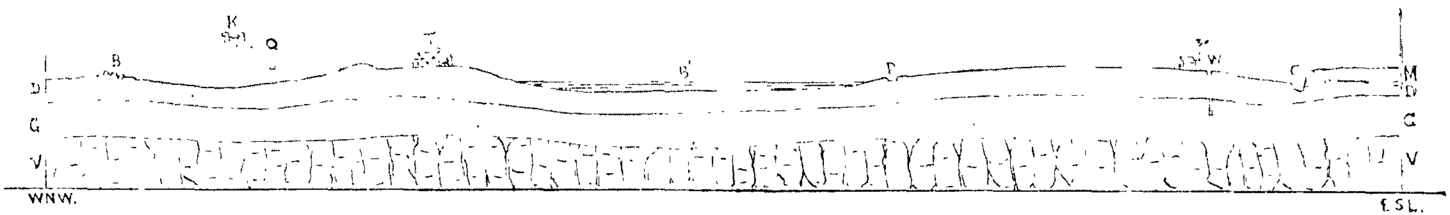


Fig. 18.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland from WNW. to ESE. through *Khimeshwar Temple*, K.; its *Quarry-sites*, Q.; *the town of Kunchri*, T.; *the Porbandar Salt-pans*, P.; Bokhira well-shaft, W.; and the Creek, C., to the NE. of Porbandar City. V.—Volcanic rocks or Bedded-lavas of the Deccan-trap Period. **G.**—Gáj (Miocene) Group of Beds, pierced by **W.**, well-shaft at Bokhira. **D.**—Dwárka (Plio Pleistocene) Group of Beds, exposed as 'Breakers,' **B.**, at low-tide mark; as flagstones at **T.**, Kunchri and neighbourhood; and as Ruddy Rubble at the surface of **W.**, near Bokhira, and the Creek-cutting, **C.**, at Porbandar City. **Q.**—Quarry near Khimeshwar Temple or the Shoreland-dunes, **B'.**—Brine-backwater of the Salt-pans area. **M.** Basement crust of Miliolite, capping the Porbandar Creek-scarp.

ing peculiarities. Primarily they are, like the rocks of abyssal and hypabyssal origin, divided according to their chemical composition into acid, intermediate, basic and ultra-basic groups. Again, among the acid volcanics, subdivisions were instituted, based upon physical distinctions, to constitute *families*, and the now generally accepted name *Rhyolite*, from the Greek *rheo*, to flow, and *lithos*, a stone, was happily chosen by BARON F. VON RICHTHOFEN*, to express the circumstance that *flow structures* usually characterise the members of this family of rocks.

Varieties and Uses of the Rhyolites of Porbandar State.

As already noted, the acid volcanics or rhyolites of Porbandar State are divisible into three main varieties; of which the first, or glassy kind, obsidian, is of scientific interest rather than of commercial importance. As museum specimens and for purposes of instruction, the stone may be said to have a market-value; while its outward resemblance to coal has more than once proved to be disastrously misleading. For instance, the small outcrop of black obsidian by the roadside at Rojhra in Navánagar State, was, to the knowledge of the writer, recently reported upon by more than one so-called native geologist to be coal of an inferior quality; while, in the neighbouring State of Gondal, at Osham Hill, another native incurred considerable expense by sinking a well-shaft for several feet, and extracting many tons of black volcanic glass, before he was made aware of his mistake.

Towards the edges of the great dykes and also in the narrower vein-like intrusions of rhyolite in Porbandar State, the rock frequently exhibits a strikingly banded-structure and at the same time becomes markedly indurated so as to furnish a highly polishable material of beautiful appearance, capable of being utilised for the manufacture of quaint and ornamental smallwares. It is very doubtful, however, whether sufficiently large and continuous supplies of such material can be depended upon; but at all events, the occurrence of such stone is worthy of being borne in mind for future developments.

* *Jahrbuch der k. k. Geol. Reichsanstalt,* 1860, Bd. XI, pp. 156, 165.

Lastly, the bulk of material forming the great rhyolite-dykes of Porbandar State, is constituted by their central cores of densely compact, vertically jointed and transversely cracked stone, which sometimes exhibits spheroidal shrinkages. In a perfectly fresh condition, the ground-mass of the stone is of a subdued greyish colour flecked with very small whitish specks of felspar crystals. When weathered, the colour of the stone changes more or less deeply, into shades of fawn and brown tinged with purple and roseate hues; while the edges of the dykes are prone to become cleaved, and their surfaces to show fluxional-structure, resembling the 'grain' in wood, and a rough or trachytoid appearance to the naked eye.

Under the name of "Light Volcanic Rocks" rhyolites have been largely used in the United States of America* for general building purposes; and there is no reason why the excellent examples now found in Porbandar State should not be similarly utilised; seeing that if quarried from the central portions of the dyke, large building blocks are easily available; and, unlike the felsites, which they approximate in chemical composition and outward appearances, are capable of being readily tooled in any direction.

Rhyolite wastage, the rubbly portions at the borders of the large dykes and the abundant angular shingle almost invariably found on the slopes of the long, low ridges, although not to be compared with granophyre wastage for road-making operations, are, in every respect equal, and frequently superior to the basic volcanic dyke rocks for "metalling;" and preferable to the much harder felsites by reason of being less splintery.

Apropos of rhyolites or acid volcanic lavas and felsites or cryptocrystalline rocks of hypabyssal origin, much misconception has hitherto prevailed even among expert geologists, as to correct nomenclature. Many rhyolites of homogeneous texture have frequently been described as "felsites;" simply because hand-specimens, even when chemically analysed, show that they are com-

* "Stone Indnstry," *Mineral Resources of the United States.* Part II, Nonmetals, Washington, 1914, pp. 1284, *et sequentes.*

PLATE XVII.

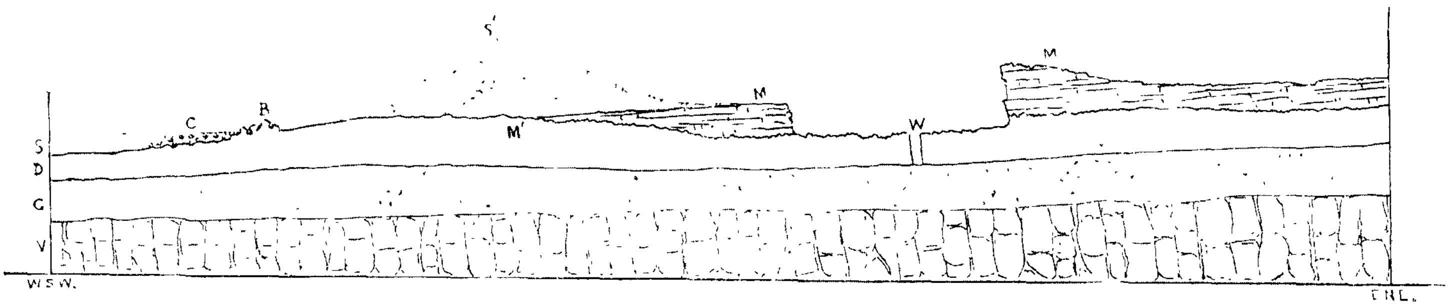


Fig. 19.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland from WSW. to ENE., through the Neighbourhood of the Lal Bungalow, Porbandar. **V.**—Volcanic rocks or Bedded-lavas of the Deccan-trap Period. **G.**—Gáj (Miocene) Group of Beds. **D.** Dwárka (Plio-Pleistocene) Group of Beds, exposed as 'Breakers,' **B.**, at low-tide mark, and at the bottom of the quarry, **W.**, near the Lál Bungalow. **S.**—Sand of beach, becoming conglomeratic and containing recent littoral marine shells at **C.** The blown sand dunes, **S'.** are shown partially covering the Dwárka beds likewise the Miliolite at **M'.**; while the Miliolite-base **M.** is exposed at the quarry resting directly upon the Dwárka beds.

posed of an intimate admixture of felspar and quartz. It is therefore desirable to draw as sharp a line of distinction as possible between these two types of rock, especially in a region where both are well represented almost side by side, and therefore liable to occasion confusion. The following observations and suggestions are therefore offered for the information and guidance of economic geologists :—

It is suggested that the term *Felsite*, shall be exclusively reserved for rocks of undoubted hypabyssal origin ; and that *Rhyolite*, in like manner shall be applied only to truly acid volcanic rocks.

Differences between Rhyolites and Felsites.

The rough and ready tests in the field are :—that, whereas a large block or boulder of felsite may, and when quite fresh usually does effectually resist the blows of a sledge-hammer, an equally unweathered block of rhyolite can always be readily trimmed with an ordinary stone-breaker's hammer. Both of the specimens, when of homogeneous, compact texture may break with a conchoidal fracture; and, when more or less porphyritic, with uneven surfaces.

In the laboratory, the felsites will be found to be intensely hard, capable of resisting severe wet or dry attrition, but prone to be splintery under great stress or sharp impacts; while their specific gravity usually exceeds 2·6. The felsites, on the other hand, are comparatively soft, can be easily ground down when subjected to attrition on a carborundum wheel, and generally show a specific gravity of 2·5, which, in specimens altered by contact metamorphism or devitrification may rise to 2·6.

Under the microscope, both felsites and rhyolites of homogeneous texture may exhibit a cryptocrystalline structure; but whereas the felsites are prone to foreshadow or even to display an ultra-microscopic, micropegmatic or microspherulitic texture, and disseminated specks and crystals of magnetite and ferro-magnesian minerals, the rhyolites are generally characterised by an abundance of microlites and crystallites orientated to indicate flow-structure; and, particularly in the very vitreous varieties, exhibit spherulites and perlitic cracks.

It will now be gathered that the comparatively limited development of rhyolites in Porbandar State are only manifested in the form of a few dykes, comprised within the area from Khistri to Nágka and thence for a few furlongs westward; while they do not appear to extend in any direction for more than about four miles from the base of the Barda Hills, which may be presumed to have stood as the focus of their eruption in Eocene times.

Mode of Occurrence, Age and Origin of the Rhyolites of Porbandar State.

This proximity to the source of eruption, is in strict accordance with the physical properties, chemical composition and other ascertained facts concerning rhyolites in general; for, it has repeatedly been observed, and tersely summarised by PROFESSOR JOHN W. JUDD, F.R.S.,* that:—" the undoubted fact that in so many volcanic regions the eruption of andesitic and trachytic rocks, which are of intermediate composition, is followed by the appearance of the differentiated products, rhyolite and basalt, which are of acid and basic composition respectively, lends not a little support to the view that under each volcanic district a reservoir of more or less completely molten rock exists, and that in these reservoirs various changes take place during the long periods of igneous activity. During the earlier period of eruption the heavier and lighter elements of the contents of these subterranean reservoirs appear to be mingled together; but in the later stages of the volcanic history of the district, the lighter or acid elements rise to the top, and the heavier or basic sink to the bottom, and we have separate eruptions of rhyolite and basalt."

The Sequence of Volcanic Lavas.

Acid lavas, among which the rhyolites furnish a first type, are comparatively more or less viscous, and consequently apt to accumulate as dykes or lava-flows in the immediate vicinity of the seat of eruption; while the more mobile basic magmas in a molten condition, which follow in their wake, naturally run past, often to great distances, frequently in the form of dykes of enormous vo-

" Volcanoes," 7th Edition, London, 1907, pp. 202, 203.

PLATE XVIII.

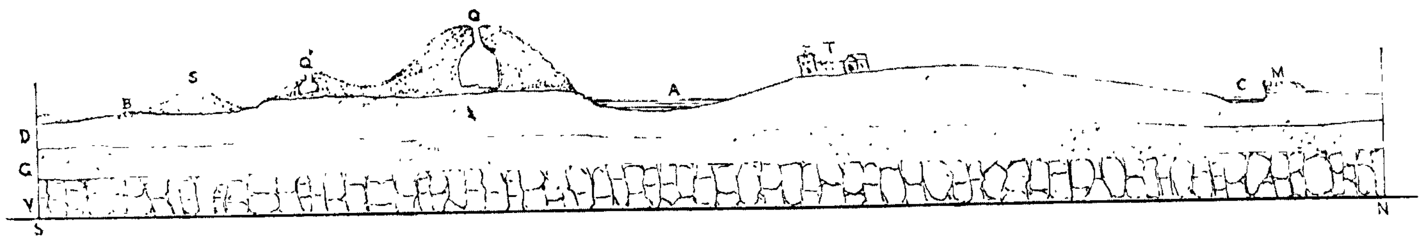


Fig. 20.—**Diagrammatic Section to show the Geological Structure of the Coastal Borderland from S. to N., through the town of Chaya. V.**—Volcanic rocks or Bedded lavas of the Deccan-trap Period. **G.**—Gáj (Miocene) Group of Beds. **D.**—Dwárka (Plio Pleistocene) Group of Beds, exposed as 'Breakers,' **B.**, at low tide mark; between the sand dune, **S.**, and consolidated sand dune quarry **Q'.**, of Mithi Khán; forming the foundations of the town, **T.**, and surroundings of Cháya; and covered by a thin crust of Miliolite, **M.**, at the Creek-scarp, **C.**, below the Ránáwáo road Bridge. **Q.**—Cháya stone, consolidated blown sand Quarries. **A.**—Alluvium from the coastal salt water floods.

lume, traversing the rocks of the countryside for many miles around the focus of eruption. This indeed, is exactly what has happened in the case under consideration ; so that, from the evidence collected by FEDDEN* and the present writer,‡ the following brief account of the formation of the Barda group of hills and their outlying eminences may here be recorded, with a view to elucidating problems or explaining occurrences that are likely to arise in the sequel.

Geographical Position of the Barda Group of Hills in Porbandar State.

Favourably situated within easy distance of the city of Porbandar, with railroad facilities around and along its southern base and direct roadways leading to places of vantage capable of being developed for the exploitation of its vast and valuable stone resources, the Barda group of Hills occupies a practically oval area, with a N. to S. major axis of about 14 miles, and an E. to W. minor axis approaching 11 miles in length, which lies but nine miles distant NE. of Porbandar Port. The relief of the hills, their principal altitudes and drainage channels, are depicted in detail upon the geological chart which accompanies this report.

By far the largest portion of this immense area,–about two-thirds of it,–still belongs to the State of Porbandar. This comprises fully two-thirds of the central zone above the minor axis, and the whole of the southern half of the space below that line. The loftiest hills of the group, at present practically inaccessible to mining and quarrying operations, are located towards the northern portions of the group and without the boundaries of the State ; but an incalculable advantage is manifestly gained from this circumstance, inasmuch as the tailing-down of the hill-slopes, their innumerable spurs, outliers and nether eminences to the S., SE., W. and SW., afford numerous excellent and easily accessible quarry-sites for the excavation and utilisation of an exceptionally large and varied range of economic stones, which only require to become generally

* "Memoirs, Geological Survey of India," Vol. XXI, Part 2, Calcutta, 1884.

† *Op. cit., ut supra*, p. 38.

known, to be eagerly sought for by intelligent and progressive builders, architects and engineers throughout the length and breadth of Imperial India. A detailed description of the nature and uses, together with optical determinations and photomicrographs of types and special varieties of these stones, coupled, as far as possible, with commercial statistics will be afforded in the sequel.

Geological Age of the Barda Group of Hills.

From the researches of W. T. BLANFORD* in Peninsular India, and the subsequent work of F. FEDDEN† in the Province of Káthiáwár, it is now generally recognised that the great Deccan-Trap Period, towards the close of which the Barda Group of hills came into existence, must be assigned as coming somewhere between the Upper Cretaceous and Lower Eocene times of the European Geological Record.

The Building of the Bardas.

Without entering into details, which would be out of place in this connection, it may be briefly stated that overwhelming evidence has been gathered to show that the Province of Káthiáwár in Upper Cretaceous days must have been literally deluged from end to end by intermittent outpourings of molten matter, seething forth from fissures in the earth's crust; to consolidate, upon cooling, into vast accumulations, now manifested by the bedded-lavas, which constitute the largest portion of the 'country-rock' of the Province.

Towards the cessation of volcanic eruption, probably with the dawn of the Eocene Epoch, a few deep-seated foci were left active; and it is certain, at all events, that one or more of these must have been situated in the region now occupied by the Barda Hills. A period of severe and prolonged denudation must next have set in, to sweep away almost every trace of accumulated ashes, agglomerates and tuffs, and to leave naught but the wreck of a huge volcano behind, shorn to the very core, and subsequently worn down by epigene reactions into a group of hypabyssal hills, with dykes

* 'Records of the Geological Survey of India,' Vol. V, Part 3, 1872, p. 92.

† 'Memoirs of the Geological Survey of India,' Vol. XXI, Part 2, 1884, pp. 19-35.

PLATE XIX.

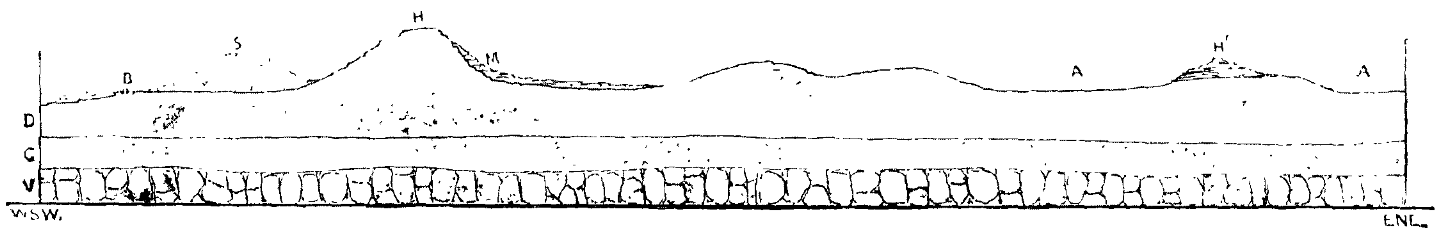


Fig. 21.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland from WSW. to ENE. through Salak Tobra and Chirora-ka-Tobra near Adodar. **V.**– Volcanic rocks or Bedded lavas of the Deccan-trap Period. **G.**– Gáj (Miocene) Group of Beds. **D.**– Dwárka (Plio Pleistocene) Group of Beds, exposed as 'Breakers,' **B.**, at low tide mark; forming the summit, **H.**, of Sálák Tobra and re exposed ENE., towards and underlying the alluvium, **A.**, of the Great Salt Marsh. **S.**– Sand dunes of Shorelands. **M.**– Miliolite on E. slope of Sálák Tobra. **H'.**—False-bedded, decomposed Limestone of Chirora ka Tobra.

and sheets of acid-lavas or rhyolites in contiguity, and later developments of far-reaching intrusions of basic-lavas, which are found to cut through the older series of bedded-lavas for many miles around.

By way of a brief digression, with a view to rendering other matters of geological interest clear, it may be noted that it was during this phase of the building of the Bardas, or, at any rate in early Tertiary times, that profound metachemic changes supervened all along the coastal areas of the Province, from Bhávnagar and around by Porbandar to the limits of the Taluka of Okhamandal and a trifle beyond, well into the territory of Navánagar State. The majority of the summits of the hog-backed hills and ridges of bedded-lavas were attacked, presumably by alternations of intense heat, (powerful sun-baking), and aqueous supersaturation, (ultra-monsoon conditions).This regional reaction would be quite sufficient to account for the laterisation of the *then* exposed areas of bedded lavas along and about the coastal countryside ; while subsequent denudation would as amply explain how it came about that only the caps of hills and isolated patches of rock-plain became converted into laterite, while their contiguous bases and adjoining grounds remained unchanged.

The Evolution of Laterite.

There cannot be the vestige of a doubt that the laterites of Káthiáwár were formed in Pre-Miocene times, for there are well-marked evidences of their being overlapped by beds of fossiliferous limonitic-limestones belonging to the marine Gáj Group of the Miocene Period, notably in the neighbourhoods of Tukra, Visáwára and elsewhere in Porbandar State. The presence of these coastal Gáj beds, of course, indicates a subsidence of the shore lands of Porbandar State, encroaching inland for a considerable distance, and possibly quite as far up as to the base of the Barda Hills, to the building of which they indirectly contribute, as will be shown in the sequel ; while their characteristic yellow-colour, is unquestionably due to limonitic staining derived from the liberated iron oxides of the laterite upon which they were principally deposited.

Commercially considered, these Gáj beds are of distinct importance; inasmuch as when segregated into sufficiently thick beds of compact and excessively fine-textured rock, they yield ornamental stones, which would be eagerly sought for if properly exploited. For example, a particularly fine stone, belonging to this type, of a rich cinnamon colour, uniform, compact texture and capable of being polished or delicately carved, has recently been named *Bhárwáralite*, by the writer, to denote its occurrence in merchantable quantity in the vicinity of the village of Bhárwára. Then again, when reduced in the subsoil zone to the condition of a uniformly soft bright-yellow marl, as at the eastern outskirts of the village of Pálakra, the marketable material known as yellow-ochre is yielded, and much esteemed for the preparation of distempers or conversion by calcination into the pigment technically termed 'light-red.'

Commercial Products of the Gaj Group of Miocene Beds in Porbandar State.

The submergence of the coastal regions during the Miocene must manifestly have been prolonged right through the Pliocene, and possibly, well into the Pleistocene Age; for the Gáj limonitic-limestones appear at numerous localities to be overlaid without any break in succession or conformity by other beds that gradually depart from a Miocene facies both in lithological characters and fossil contents. It was for these reasons that FEDDEN * found it desirable to group them together under the denomination of "Dwarka Beds," on account of their best development near the port of Dwárka in Okhamandal.

The Dwarka Group of Beds in Porbandar State.

In Porbandar State, to the north of its capital-town, the beds of the Dwárka Group are found outcropping over a very considerable area, shown by a yellow tint upon the Geological Chart; from which it will be gathered, that, like the underlying Gáj Beds, they are practically sub-coastal, and rarely encroach inland for more than about 7 miles. The beds in Porbandar State vary very much at different localities; while the natural exposures and well-shafts

* 'Memoirs of the Geological Survey of India,' Vol. XXI, Part 2, 1884, pp. 51-53.

PLATE XX.

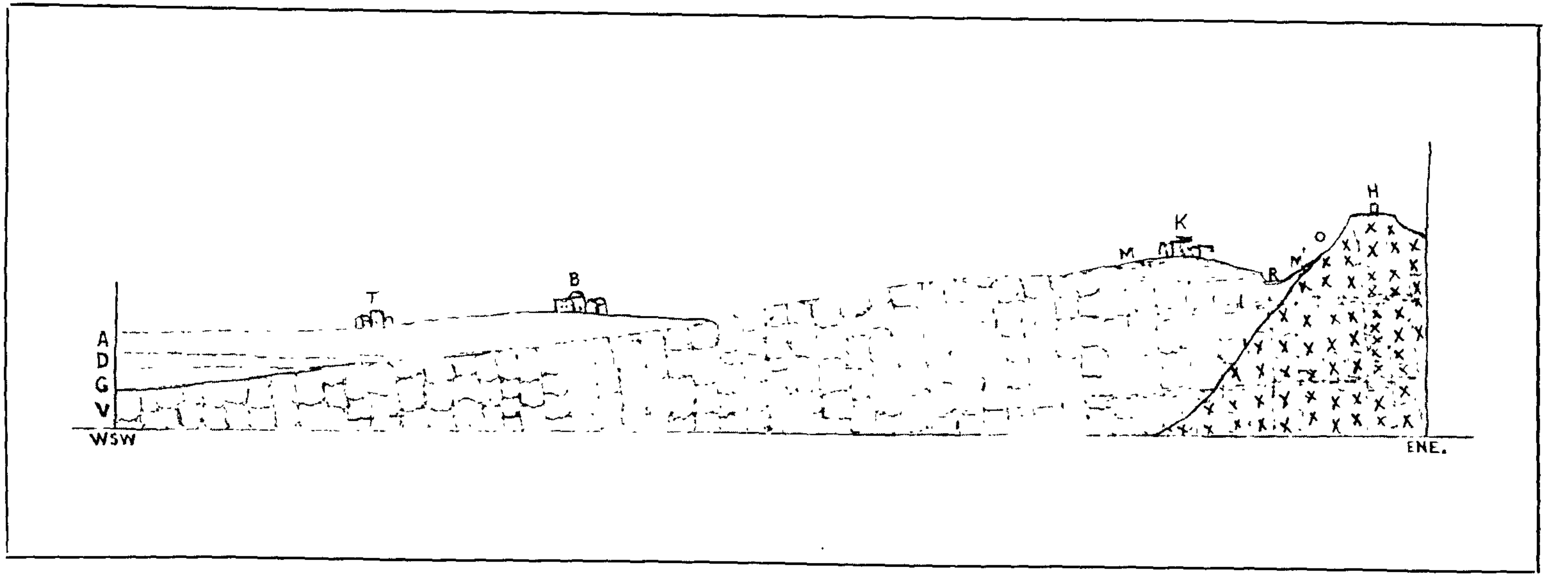


Fig. 22.—Diagrammatic Section to show the Geological Structure of the Countryside from WSW. to ENE., through the Sites of Mokal, Bapodar, Kandorna and Dhanak Dhar. **V.**—Volcanic rocks or Bedded lavas of the Deccan trap Period, exposed between Bápodar, **B.**, and Kandorna, **K.** **H.**—Dhának Dhar. **G.**—Gáj (Miocene) Group of Beds. **D.**—Dwárka (Plio Pleistocene) Group of Beds tailing down to nil. **A.**—Alluvium of the Great Salt Marsh, mingled with calcareous detritus from the northern uplands. **T.** Site of Mokal. **B.** Site of Bápodar. **K.**—Site of Kandorna. **M.**—Miliolite base at Kandorna. **M[1].**—Miliolite base deposits at foot of Dhának Dhár. **O.**—Small excavation in hypabyssal rock on slope of Dhának Dhár. **R.** Bed of River Minsar.

do not afford sufficient data upon which to divide them into sub-groups. Nevertheless, there is sufficient evidence in all cases, to enable one to assign any particular bed, or sequence of beds, to the major group.

For example, at the port of Miáni, the westward scarp of the Meda Creek upon which the Level Datum Pillar stands, shows a 3 to 6 ft. scarp of coarse honeycombed miliolite-limestone, resting upon a 10 ft. cliff of a compact, shelly but flaggy limestone, one part of which appears to be coralliferous. These beds directly overlie a substratum of brecciated fossiliferous conglomerate, full of fragments of very characteristic Gáj limonitic-limestone, which at once serves to proclaim its own-age, as well as that of the beds betwixt itself and the capping of miliolite, to belong to the period of the Dwárka Group.

Fringing Coral-reef at Visawara Creek-mouth.

Another, somewhat similar, but more extensive exposure at the mouth of Visáwára Creek, a trifle over 6 miles farther SE. on the Porbandar State coast, shows the remains of a large fringing coral reef, (capped by a local gritty bed surmounted by miliolite), which was clearly grown upon beds essentially similar to those forming the Creek-scarp at Miáni. These rocks rest upon a compact, light-coloured, flaggy limestone, the precise nature of which awaits determination, but which undoubtedly also, is of Post-Miocene age. Closely resembling, if not identical with this last-named rock, there may be seen large slabs of stone, azoic to the naked-eye, which crown the summit of a hillock, 5½ furlongs NNE. by NE. of the coastal village of Tukra and some 2¾ miles NNW. of Visáwára Creek-mouth. The basement beds of this stone gradually pass below into a fossiliferous conglomerate, and this, in its turn directly overlies beds of Gaj limonitic-limestone; so that evidence is here afforded that the former belong to the Dwárka Group.

Still farther south-eastward, as at Sirinagar, Kátela, Kunchri and Porbandar-City, as well as inland in the directions of Degám, Kolikhara and on the road to Ránáwáo, the outcrop of the pale-

coloured, almost white flagstones grows more and more pronounced; and if any further confirmation were wanted to show that these belong to the Dwarka Group, it may be noted that many instances have been recorded in detail of their direct superposition over well-marked beds of Gáj limonitic-limestone in the monthly reconnaissance reports on the structural geology of the State. More especially on the surface at the NNW. side of Sirinagar and in well-shafts in the neighbourhoods of such widely separated situations as Renáwára, Degám, Kolikhara and Bokhira are these occurrences made plainly manifest.

Pale-coloured Flagstones of the Dwarka Group.

Alongside the stretch of sea-shore from Kunchri to Porbandar-City the abovenoted Dwárka flagstones, are overlapped by an inconsiderable thickness of consolidated and consolidating shell-sand; but farther inland, the upper zone of the group is characterised by a more or less deep russet-coloured, much cancellated, sandy limestone;-the precise nature of which remains to be determined by microscopical examination. This stone, together with considerable depths below of a rubbly conglomerate, may be seen to advantage in sundry deep well-shafts immediately ENE. of Kátela and in the SE. outskirts of Sirinagar; while superficial outcrops occur all the way from the east of Bokhira to the old site of Arniála and beyond.

Russet-coloured, Rubbly, Limestone of the Dwarka Group.

The total thickness of the Dwárka Group of beds is stated by FEDDEN*,-who had the opportunity of examining the entire formation,-to be inconsiderable; but, even in its very limited development in Porbandar State it presents quite a varied assortment of rocks; which, taken generally, exhibit a littoral or at most a comparatively shallow-sea origin, and are constituted chiefly by conglomerates, a few fossiliferous zones, consolidated shell-sands, compact rubbly-rocks and flagstones frequently false-bedded.

Commercial Products of the Dwarka, Plio-Pleistocene, Group of Beds.

* *Loco citato*, p. 51.

PLATE XXI.

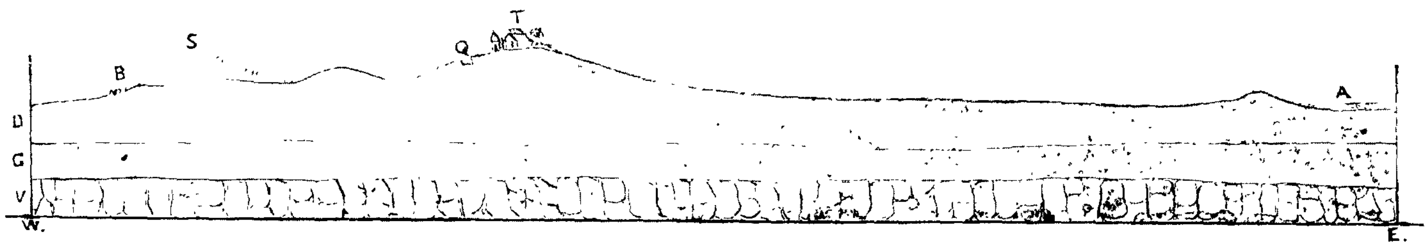


Fig. 23.—**Diagrammatic Section to show the Geological Structure of the Coastal Borderland from W. to E. through the Parallel of Tunkra.** **V.**—Volcanic rocks or Bedded lavas of the Deccan trap Period. **G.**—Gáj (Miocene) Group of Beds. **D.**—Dwárka (Plio Pleistocene) Group of Beds, showing exposure of 'Breakers,' **B.**, at low tide mark, and quarry, **Q.**, of exceptionally thick and compact flagstones. **S.**—Shoreland sand dunes. **T.**—Site of village of Tunkra. **A.**—Alluvium of the Great Salt Marsh.

The consolidated shell-sands occasionally yield sound blocks of whitish and pale-grey stone of compact granular texture, easily tooled and polishable; but, as a rule are seldom available in thicknesses of more than 4 to 6 inches. More frequently, they yield an abundance of tough, rubbly stone, which has been very largely utilised for local road-metal, but is not sufficiently durable to command export market prices. The russet-coloured, rubbly, indurated limestones of the group, are likewise extensively employed locally for road-making, by reason of their abundance and cheapness. On the other hand, the pale-coloured flagstones, which, by the way, sometimes present dark grey-brown and even blackish varieties, (as recorded in the reconnaissance reports), very often bear being extracted in large slabs of considerable thickness, and are in great local demand for cutting into building blocks, for the foundations of dwelling-houses. These are variously known according to their sites, as "Kunchri-stone", "Degam-stone," but, needless to note, they do not command prices sufficient to justify exportation.

It is more than probable that the upper zones of the Dwárka Group, which present a still unclassified foraminiferal facies, were deposited in early Pleistocene times, during which there must have been a general elevation of the land throughout the coastal regions of the Province; inasmuch as they now obtain in the form of raised-beaches. Subsequently, however, after they had undergone appreciable erosion; frequently having been swept entirely away at sundry places, so as to leave the underlying Gáj Group of beds exposed, it is manifest, that during the close of the 'Great Ice Age', a universal subsidence, not merely of its coastal regions, but of the entire Province, must have supervened.

Subsidence of the Province during the Pleistocene Period.

There are evidences everywhere, in confirmation of the fact that this general depression gradually took effect from SW. to NE., thereby causing a submergence of the whole of the Province, with the exception of its extreme north-eastern districts. The subsidence of the land must indeed have been so stupendous as to

have left naught but the summits of its hills in the semblance of islands studding the Pleistocene sea; and, upon the subsequent re-elevation, which is even now progressing, unmistakable records of devastation and regeneration have left their impress upon the physiographical features of the countryside; its hog-backed hills of bedded-lavas, wide stretches of rock-plains, and the indelible limitation-lines of sedimentary deposits upon its highland slopes.

Sub-aerial denudation coupled with the wearing away of the coastal and adjoining rocks, right up to the base of the Bardas during Tertiary and early Post-Tertiary times must surely have altered the general configuration of the lower lying and coastal lands of the country; but during the critical period of its subsidence in Pleistocene days, the whole of the submerged regions must likewise have undergone a complete transformation by the deposition of a very considerable thickness of sedimentary matter.

Deposition of the "Miliolite."

To this sedimentary matter, constituted for the best part of conglomerates and more or less pure limestones, DR. CARTER * gave the name of "Miliolite";–a term, which, although not strictly correct, might nevertheless be retained on account of its long and general association with the Pleistocene foraminiferal limestones of Káthiáwár, commercially known as "Porbandar-stone."

Varying Thickness of the Miliolite Deposits in the Province of Kathiawar.

It is clear that an enormous thickness of miliolite beds must have been deposited during the Pleistocene Age, mainly of the nature of foraminiferal limestones; for these have left their lines of limitation on the hill-slopes throughout the length and breadth of the Province. For example, in referring to the conical hill of Chotila on the high-road midway between Wadhwán and Rájkôt, which stands 1,173 feet above the mean sea-level, and is about 550 feet higher than the surrounding plains, FEDDEN notes §, that "in the

* *Geological Papers on Western India*, Bombay, 1857, p. 756.

§ 'Memoirs of the Geological Survey of India', Vol. XXI., Part 2, p. 56.

PLATE XXII.

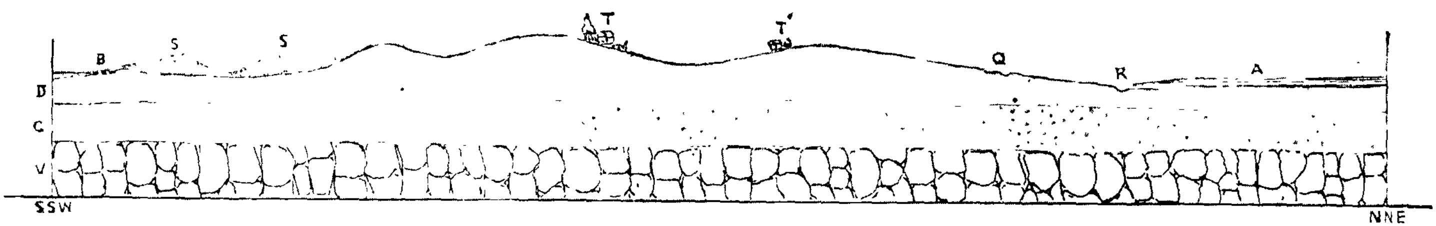


Fig. 24.—Diagrammatic Section to show the Geological Structure of the Coastal Borderland from SSW. to NNE. through the sites of Balej and Rabarikhira. V.—Volcanic rocks or Bedded lavas of the Deccan trap Period. **G.**—Gáj (Miocene) Group of Beds. **D.**—Dwárka (Plio-Pleistocene) Group of Beds, showing exposure of 'Breakers' at low-tide mark; and outcropping ridges and depressions all the way NNE., until obscured by the river, **R.**, and the alluvium, **A.**, of the elevated bed of the Great Salt Marsh. **S., S.,** Shoreland sand dunes. **T.**—Site of Balej. **T'.**—Site of Rábarikhira. **Q.**—Surface excavations for Dwárka flagstones.

fringe of miliolite which occurs around its truncated top, there is conclusive evidence that this hill, and all the surrounding country, has been beneath the sea in comparatively recent times. Probably the greater part of the peninsula was depressed at least 1,170 feet lower than it stands at the present day." Again, the same writer* observes :-" The cliffs of Diu island are 50 feet high, and there are quarries in the interior equally deep, which have not been pierced through this peculiar rock. At Jáferábád, the cliffs rise to 100 feet, and again at Gopnâth they cannot be much less; but the section at the two latter localities is not made up entirely of the limestone."

In Porbandar State, the coastal deposits of miliolite, are generally arenaceous, coarse-grained and more or less discoloured;- buff, brown or greyish-brown. They are also much vacuolated or pierced by variously sized cylindrical tubes or perforations, which sometimes branch and form anastomoses;-occasionally so closely as to impart a honeycombed aspect to the stone. It is probable, that as these channels invariably obtain in false-bedded or other portions of a distinctly littoral origin, they were originally occupied by some kind of easily decayable organic matter,-presumably by the thallus of laminarian *Algæ*.

Cause of Perforations in the Beds of Miliolite.

At Miáni, the coastal miliolite deposits slightly exceed a total thickness of about 20 feet, and can be seen to overlie tolerably thick beds of shelly and coralliferous limestone belonging to the Dwárka Group of beds. At Tukra, by the sea, the miliolite overlapping both Dwarka and Gáj limestones, is found resting upon caps of laterite, and is in part transformed thereby into a dark reddish-purple stone, through the diffusion of a concentrated iron-stain; while all along the borders of the sea-shore from Miáni to Porbandar-City, a more or less continuous, low ridge of miliolite is left undenuded, covering at times the remains of Dwarka flagstones or beds of Gáj limonitic-limestones.

Varying Thickness of Miliolite Deposits in Porbandar State.

The succession of strata thus identified as occurring all along the coast-line, has been traced more or less inland, almost up to the

* *Op. cit.*, pp. 54-55.

base of the Barda hills ; and the outcrops of the beds belonging to each separate group, such as the Dwarka and the Gáj beds, and the sheets of bedded-lava, are duly defined by coventional colours upon the Geological Chart which accompanies this report.

The Main-Miliolites of the Adatiana Heights near Ranawao.

By far the most important development of miliolite in the Province however, and one which has contributed no mean quota to the building of the Bardas, is to be found marking the limestone vertical limit, fully 300 feet above the mean level of the sea. At this conveniently situated locality, known as the Ádatiána Heights, fringing the south-western flanks of the lofty hills, an exceptionally deep cradle is formed, wherein the miliolite has found an abiding place, filling up the hollows and gorges of the hillsides with thick tiers of merchantable stone, composed of basement beds of coarse, indurated, obliquely laminated strata, passing gradually into a central thick zone of superlatively fine stone and capped above by other coarsely-textured beds at the limit line.

Horizontal and Vertical Variations in Texture and Composition of the Miliolites.

As these beds of stone necessarily conform to the general mode of occurrence of sedimentary marine deposits by assuming lenticular contours, it naturally follows that the texture of the stone varies not only vertically but horizontally. The relation of the miliolite to the underlying hypabyssal rock, without any intervening thickness of conglomerate, is admirably shown by a railway-cutting at the base of the group near Ránáwáo-station,-Fig. 12,-where the false-bedded miliolite is shown resting directly upon what was once the denuded and partially decayed surface of the mountain-massive. The thickness of the deposits, which is insignificant at the exposure abovenoted, gradually increases with the altitude, along the course of the railway-siding from Ránáwáo-Station to the heights of Ádatiána ; but the character of the stone may be seen to vary from place to place, during the ascent. In the neighbourhood of Ránâwáo-Station, the coarse, ruddy-coloured stone, exhibits, what might at

first sight be mistaken for a decided dip; but, upon more careful examination, the up-turned edges of the thin strata, are found to be merely caused by false-bedding and subsequent surface erosion.

Coarse Miliolite resting upon a Substratum of Sand at Jambuvanti Bhoira.

Approximately $1\frac{1}{4}$ miles NW. of Ránáwáo-Station, there is a natural shaft leading down to a subterranean tunnel, doubtless caused by underground waters, which has been made accessible by a spiral stairway cut into the sides of the original shaft. The rock of this "Jambuvanti *Bhoira*, or cave,– as it has been named after one of the queens of the Hindu deity Krishna,–consists of beds of a coarsely textured, buff coloured and obliquely laminated miliolite of but poor commercial value, to a total thickness of about 25 feet, resting directly upon a thick, (5 to 7 feet), substratum of a dark-brown sand full of glittering particles which await optical determination.* This bedding of slightly coherent sand, has, since the deposition and consolidation of the overlying miliolite, been almost entirely swept away by an underground stream formed by periodic percolating waters, to form the subterranean cave noted above.

The Main-Miliolite Deposits of the Adatiana Heights.

From the Railway-Station of Ránáwáo, a gradually ascending siding passes northward for about a mile, to the site of the main miliolite deposits along the deep cradle of the lofty-hills, where they form an irregular ridge trending from NW. to SE., hereinafter to be called the "Ádatiána Heights;"– by reason of their elevated situation overlooking the village of Ádatiána. The railway-siding traverses the entire length of the heights for a distance of over 3 miles, and is conveniently provided with a succession of quarry-platforms, to which the excavated stone is carted or carried from the extensive series of quarries adjoining the railway-line. The entire deposit is systematically divided into plots, each bearing some distinctive native name, such as, "Bhoyrawári," "Kundlawári," "Babulwári," "Rânwári" and so

* This sand has been proved by the analysis of R.E.J.M'CULLY, the expert chemist to the Porbandar Cement Works, to be nothing more nor less than thoroughly decomposed granophyre or rock of the mountain-massive.

forth ; while each plot is subdivided into duly numbered quarry-allotments, which are leased out by the State to approved contractors.

Total Thickness of the Miliolite Deposits forming the Adatiana Heights.

The total thickness of the miliolite beds, forming the Ádatiána heights, must be very considerable, and is unquestionably the deepest and most extensive of its kind in all Káthiáwár ; that is to say, there is nowhere else in the Province, such a large development of merchantable, white limestone of the kind specified commercially as "Porbandar Building-stone." Towards the original commencement of the excavations, a well-shaft has been sunk through the miliolite to a depth of over 80 feet, where the water-level is struck at the practically impervious underlying surface of the mountain-massive. The open-quarry excavations, as may be surmised, do not penetrate to the utmost depths of the deposit ; which, moreover, varies in thickness from place to place ; but excavations of from 10 to 30 feet or a trifle more, are generally found sufficient for all practical purposes, by reason of the fact, that as the basement beds are approached, the stone grows indurated and finally so full of adventitious particles from the underlying hypabyssal rocks, as to be commercially worthless. So too, as has already been noted, the uppermost beds are prone to be crowded with gritty and sandy layers or grains generally disseminated through the substance of the stone.

Commercial Grading of Merchantable Miliolites.

As a rule the central, more or less horizontally laminated beds of the miliolite, yield the highest grades of stone, and these may be specified to consist of a practically uniform, fine and close-grained texture, capable of being extracted in large blocks of over one, up to two or three feet in thickness without any tendency to part into slabs ; capable of being delicately carved and even undercut ; and of resisting a crushing strain of about 165 tons per square foot. Stone of the above character, has been in increasing demand for many years, for the erection of fine frontages, columns and capitals, friezes and balustrades in palaces, temples, public-buildings and mansions, not only locally but in the chief

PLATE XXIII.

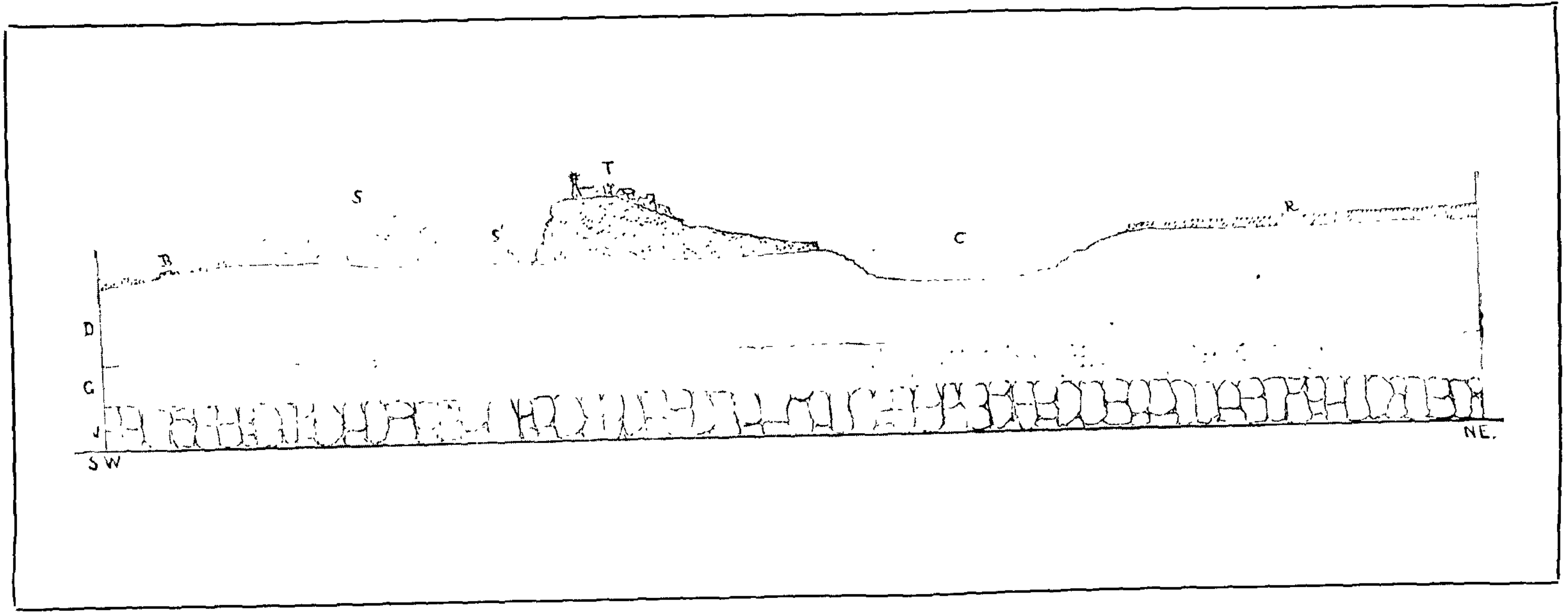


Fig. 25. - **Diagrammatic Section to show the Geological Structure of the Coastal Borderland from SW. to NE. through the Town of Navibandar. V.** Volcanic rocks or Bedded-lavas of the Deccan trap Period. **G.** - Gáj (Miocene) Group of Beds. **D.** Dwárka (Plio Pleistocene) Group of Beds, showing exposure of 'Breakers,' **B.**, at low tide mark. **S.**—Sand dunes, the lower levels of which at **S'.**, and also the eminence on which the town, **T.**, stands, have been consolidated into stone. **C.** Creek of the Bhádar river. **R.** -Recent deposits of my, gravelly and shelly conglomerate, approaching and beyond Sikása.

cities of India:—Bombay, Colombo, Karachi, Madras, Calcutta and Rangoon. The quarry prices, f. o. b. at Porbandar average 3 annas per cubic foot.

The second grade of miliolites is principally derived from the sub-centrally situated zones of the huge deposits; but, while being available in building blocks of ordinary, (18 by 12 by 9 inches), and even much larger sizes, are more or less constituted by alternately fine and coarsely textured laminæ. This necessitates the laying down of blocks with their laminæ horizontally disposed, so as to prevent a liability to splitting by superincumbent pressure. When thus placed, this second grade of stone is capable of withstanding a much greater crushing strain than the finer qualities of more uniformly textured or homogenously grained stone; but has the disadvantages of weathering into ridges and furrows after the lapse of many years, and of being unsuitable for any kind of carving, save the simplest forms of bas-relief. The laminæ of the stone vary from less than a-quarter to slightly over half an inch in thickness, and the blocks are chiefly indicated for the inner walls of public-buildings and for the erection of out-houses, ordinary dwelling-houses, warehouses and the like. The quarry prices f. o. b. at Porbandar docks, vary from two annas to two annas and a-half per cubic foot.

A third grade of miliolite, derived from the coarser uppermost and also from the super-basement beds of the deposits, is constituted by indurated stone, generally more closely and thinly laminated than the foregoing varieties, which rifts into slabs or flags varying in thickness from about $1\frac{1}{2}$ to $2\frac{1}{2}$ or even 3 inches. These stones are very largely used locally for lining well-shafts, and the laying down of floors, and are roughly hewn to regulation sizes and sold at prices as follows:—3 feet by $1\frac{1}{2}$ feet by $2\frac{1}{2}$ inches, Rs. 15; $2\frac{1}{2}$ feet by $1\frac{3}{4}$ feet by 2 inches, Rs. 10; and 2 feet by $1\frac{1}{8}$ feet by 2 inches or less at Rs. 8 per 100 slabs.

It is much to be deplored, on the score of strict economy, that miliolite has ever been used for the building of steps and stairways, for the laying down of landings and floors or for situations

subjected to constant wear and tear; especially in a country abounding, almost to excess, in easily workable, light and dark volcanic rocks; but the "custom of the country" and the ease and cheapness with which the inferior grades of this material can be tooled and supplied, are strong arguments in favour of its continued use locally, which cannot lightly be combated and overcome. Doubtless, the day will dawn when a right appreciation of the merits of other building materials,–such as blue-black basalts and dolerites, fawn-coloured and grey rhyolites and the intensely hard felsites and ultra-tough and strong granophyres, will finally oust the comparatively soft and much less durable limestones, for positions subjected to intense stress and attrition, from the field altogether; but the initiative still remains to be taken in India by both architects and builders, before any salutary reformation can be expected.

Plea for the Substitution of Strong Stone in place of Coarse Miliolites for Steps, Floors and Pavements.

Ádatiána Heights, the busy scene of the great miliolite industry of Porbandar State, marks the limestone-limit at a height of about 300 feet above the mean sea-level;–for the deposits slope gently, for a few hundred yards, as a stone-strewn stretch of almost level land, up to the steep slope of the lofty hills and beetling crags above. From a distance, the altitude of the Heights and long line of quarry-workings is clearly indicated by the piles of wastage dumped around the open-pit mouths, as shown at *x-x*, in the photograph, Fig. 13, which was taken from a distance of slightly over one mile from the NE. side of the village of Ádatiána.

Limestone-limit on the Adatiana Heights

Quarrying operations have already been carried to practically the end of the deep deposits of miliolite, which cease almost abruptly about 1¾ miles NNE. of Ádatiána, where small workable beds of untouched stone of tolerably good quality flank the sides of a deep mountain runnel called Sij Jhár; but, in a westward direction, descending to the village of Ádatiána and its surrounding plains, the miliolite beds of compact stone thin down to but a

few feet in thickness, and no longer lie directly upon the mountain-massive, but are underlaid by a thick stratum of more or less brecciated conglomerate, the upper layers of which are frequently concretionary to a large degree.

Good Granophyre and other Quarry-sites near Bhil Jhar.

Continuing northward after the cessation of the deep deposits of the Ádatiána Heights, the base of the hills beyond Sij Jhár, is merely crusted here and there with patches and small mounds of miliolite full of impurities, derived from the underlying hypabyssal rocks; but hereabouts, the hill-spurs and slopes are admirably adapted for large quarry sites capable of yielding a rich variety of valuable felsites and granophyres. Such quarry sites are indicated on the Coloured Geological Chart by small circles each bearing a registered number corresponding with the registered number on the list of rocks gathered by the Geological Survey Department for the State Museum Collection.

About one mile almost due north of the NW. termination of the extensive quarry sites on Ádatiána Heights several spurs from contiguous hills converge to from an ascendable gorge called " Bhil Jhar, " to which a rugged pathway leads up to a pass and down beyond into the valley of Sathvirda Nes. A photograph,-fig. 14,-was taken of this site, as affording an exceptionally fine view of the contours and general physiographical features distinctive of hills of hypabyssal in contradistinction to those of volcanic origin.

To return to the subject of the miliolite deposits of Porbandar State:—It would be almost impossible, unless by wearisome and unprofitable details, to describe the spread of the countless patches and mounds of the material that have been left undenuded between the Bardas and the sea-shore; but a correct estimate thereof may nevertheless be gathered by a glance at the Geological Chart, wherein the comparatively recent deposits of miliolite, are shown by closely parallel blue lines. From these it may be observed, that the vast bulk of the miliolites, (which must,-upon the final emergence of the land from the Pleistocene sea,-have covered the entire countryside of the State below the line of limit, 300 feet above the

sea-level), has been swept away by denudation, leaving only a comparatively insignificant portion behind to fill the recesses and encrust sundry favoured spaces over the length and breadth of the land.

It thus happens that the remains of the miliolite are found covering all kinds of previously formed rock; and when the basement beds of any particular deposit of miliolite are examined they invariably show inclusions of the subjacent and other local structures, frequently in large brecciated or rounded fragments, but oftener in small particles, pebbles and grains of microscopic dimensions. Typical examples of these will be given in a future report, with analyses, microscopical determinations of the mineral or other units, and their relations to one another pictorially illustrated by photomicrographs ;—with a view to demonstrating, beyond dispute, the origin, precise nature and economic value of each selected type of stone.

DAMODARDAS PRINTING HOUSE.—RAJKOT C. S.

PLATE XXIV.

Fig. 26.—Conservation of Coastal Blown-sand. The perennial purple belled creeper *Ipomæa biloba* is here shown binding the surface of the sand dune firmly, into a more or less level topped low ridge, immediately adjoining the beach, 200 feet from low tide mark, 1½ miles SE. by SSE. of Navibandar. From a *photograph* by E. HOWARD ADYE, F.G.S., taken on the 9th April, 1916.

Plate XXV.

Fig. 27.—**Conservation of Coastal Blown-sand.**—Through the agency of sedges, principally of *Cyperus stolonifer-us* and *C. rotundus*, the sand is here held together, by tufts of growth, into a close succession of miniature mounds and short ridges of but a few inches in height, yet quite sufficient to prevent very considerable quantities from being blown farther inland. From a *photograph* by E. Howard Adye, F.G.S., on the lee-side of site shown by Fig. 26. Taken on the 9th April, 1916.

THIRD QUARTERLY REPORT

ON

THE ECONOMIC GEOLOGY OF PORBANDAR STATE.

BY

E. HOWARD ADYE, F.G.S., etc.,

Director, Geological Survey of Porbandar State.

December, 1915; January and February, 1916.

OBSERVATIONS on the economic value of 'Porbandar-stone' or miliolite-limestone would be sadly deficient without some *definite* information concerning the comparative strength and chemical composition of the material; the first for the guidance of architects and builders, and the second for the satisfaction of manufacturers of building-materials of the nature of limes, mortars, concretes and cements.

Average Crushing-strain of High-grade 'Porbandar-stone.'

As a rule, architects and builders now-a-days very properly insist upon specifications to denote what is technically termed the 'crushing-strain' of stone tendered for the erection of public-buildings and the better classes of dwelling-houses; for which the best grades of Porbandar-stone have so long been famous, not merely locally, but throughout the length and breadth of the Indian Empire. The quarry-holders at the Adatiána Heights near Ránáwáo Station in Porbandar State, whence the finest qualities of miliolite are exclusively drawn, are usually content to vaguely quote the rumour that the best 'white-stone' or *dora-pana,* as they call it, will withstand a crushing strain of about 2,200 lbs. per square inch. Fortunately, however, the results of accurate tests by P. G. MESSENT, M. INST. C.E., are now available;* and they give the crushing strain, per square foot, at 165 tons 14 cwt. This then may be taken as substantially correct, presumably for blocks horizontally laid, with reference to their lamination.

* 'British and Foreign Building Stones' by JOHN WATSON, Cambridge University Press, 1911, p. 428.—In a letter to the writer the author points out that Porbandar-stone has, by misadventure, been classified as a sandstone.

Chemical Composition of 'Porbandar-stone.'

Chemically considered, Porbandar-stone consists essentially of carbonate of lime, in a practically pure condition, in the highest grades of the stone, when in a perfectly fresh and stable state, with only appreciable proportions of magnesia, silica, iron and alumina, and undetermined alkalies of small importance. The stone wastage, of which enormous quantities are always available—on account of the primitive methods of extraction in vogue at the quarry sites—consequently yields lime of an exceptionally pure and superior quality;—well adapted, when kilned for the use of builders, and also as the basis for high-class cement-making. For the latter purpose it is being extensively employed by THE INDIAN CEMENT COMPANY, LIMITED, at their elaborately equipped works in Porbandar City, and an analysis of a typical sample of the stone recently made by R. E. J. M'CULLY, the Company's analyst, is here recorded* as being strictly in accordance with the writer's microscopical determinations.

Water	·02
Carbonic Acid	41·96
Silica	1·96
Oxide of Iron and Alumina ..	1·50
Lime	51·33
Magnesia	1·98
Alkalies	1·25
	100·00

Definition of the Terms Structure and Texture.

In general geology the term *structure* is usually employed to denote those larger features connected with the ways in which the materials of the earth's crust are commonly disposed; such as the stratification, eruption, intrusion, jointing, metamorphism and so forth, of rocks; while the word *texture* has been reserved to signify the character, comparative sizes and relative disposition of their mineral units. Since the introduction of the microscope as a means for geological research, however, *structure* has been increasingly employed to indicate—as in biological histology—the intimate nature, condition and modes of association of mineral aggregates; and, in that modified sense, will it be used in the sequel devoted to the optical determination of the stones of Porbandar State.

* By permission of R. SYDNEY SYMONS, Manager, Cement Works, Porbandar.

PLATE XXVI.

Fig. 28.—Conservation of Coastal Blown-sand.—Sandy *roches moutonnées*, caused by close growths of clumps of *Hydrophylax maritima*; and, at other places, of *Heliotropium ovalifolium* and *H. indicum*. These serve to arrest the sand into small mounds, which, from a distance, might be mistaken for the backs of a flock of sheep. From a *photograph* by E. HOWARD ADYE, F.G.S., about 250 yards inland from the site shown by Fig. 26. Taken on the 9th April, 1916.

Miliolite under the Microscope.

Under the microscope, properly prepared sections of Porbandar-stone or miliolite-limestone may be seen (aided by varying powers of the instrument and aecessories for the modification and adjustment of light) to consist essentially of a number of more or less rounded derived or *clastic* particles held together by a cementing matrix of small crystals of carbonate of lime. The clastic particles may be uniform in both nature and dimensions, and compactly cemented together by a perfectly fresh and crystal-clear mosaic of calcite. When such happens to be the case in sections of true samples, cut in a variety of directions, or, at the very least, both parallel to and across the lamination, and the clastic particles moreover give a measurement varying from about $\frac{1}{200}$ to $\frac{1}{50}$ of an inch in diameter, the stone may unhesitatingly be placed in the first or highest commercial grade.*

Variations, either in the nature or the sizes of the grains, or deficiencies, discolorations, turbidity, etc., in the cementing material, are sufficient to determine the proportionate inferiority of the stone, so that microscopic examination in these instances may be relied upon as an unerring guide to the quality of the rock. A first grade stone may thus be subdivided into two or more commercial qualities ; but, when the thin laminæ of the stone differ in texture—alternately finer and coarser grained—the sample should be classed as second grade. Third grade miliolites, in like manner, may be recognised microscopically by the greater loss of uniformity in the sizes of their clastic units, the variation in the nature thereof and the tendency to become flaggy in bulk, so that thick blocks for building purposes are not available.

In order to demonstrate beyond dispute, the precise nature and condition of the clastic units, the character of the cementing material, the relation of the particles to one another, and the proportions in which they are manifested in the texture of stone suitable for economic use, it will be necessary to place on record a series of photomicrographs from preparations of typical samples with explanatory text—and this shall be done in a special chapter at the end of these reports.

Sedimentary and not Sub-aerial Origin of Miliolite.

Miliolite-limestone as a true sedimentary deposit of principally marine-littoral, but also of deeper sea origin, so very closely resembles the blown-sands of sub-ærial consolidation, that it would be difficult, if not hopeless, to try to distinguish between the two types of stone by laboratory

* See Plate XX, Upper Figure, 'Memoir on the Economic Geology of Navánagar State,' by E. HOWARD ADYE, Bombay, 1914.

research alone. In the field, however, the distinction becomes more or less plainly manifest, and in order to render this quite clear, a few examples may here be culled from the pages of the writer's reconnaissance note-book as follows:—

Geological Structure of the Coastal Borderland in the Neighbourhood of Miani.

Geotectonic memoranda on the coastal borderland of Porbandar State show that at its most northerly limit, represented by the Meda Creek and spit-bound harbour of Miáni, the æolian sands sweep inland for a mile or more, forming considerable dunes, for about half that distance; but that the blown particles are checked to a large extent from farther incursions by a long, low ridge of Dwárka-limestone capped by a crust of miliolite. Both of these formations rise prominently in the immediate neighbourhood of Miáni, the miliolite occurring as a deeply-quarried eminence on the south side of the town and tailing down to almost nil at its northern aspect; while the Dwárka-limestone, differentiated to show a fringing coral-reef-scarp, juts boldly from beneath to face the Meda Creek on its eastward side. Both again, are obscured by the blown-sand to reappear far south at the low-tide mark and as windward scarps on the Arabian sea-board.

Precipitation of Selenitic Gypsum in the Salt Marsh of the Meda Creek near Miani.

The great Wartu river, flowing westward with the accumulated surface drainage from the northern heights of the Barda Group of hills augmented by supplies from the bedded-lava uplands of Gop and other parts of Navánagar State, breaks up into innumerable lesser channels to ultimately discharge into the upper reaches of the Meda Creek; while the inrush of the tidal waves is carried far inland to contribute to the formation of a widespread saliniferous marsh, so that the meeting of the waters—the fresh and the salt—fulfils the natural conditions, upon due evaporation for the precipitation of gypsum, which is found in abundant flakes of selenite, unfortunately too freely mixed with alluvial mud to be of much value.

Geological Structure of the Coastal Borderland at the Parallel of Tukra.

To return to the coastal borderland:—The miliolite is manifested SE. of the Meda Creek mouth in the form of gradually decreasing bluffs or low sea-scraps with inconsiderable sand dunes above and a shelving beach below, through which breakers of Dwárka-limestone emerge at low-tide mark; and these conditions practically prevail for fully $4\frac{1}{4}$ miles SE. to the parallel of Tukra. At Tukra, however, the borderland (which, for the sake of conventional description, may be limited to a mile and a-half in width), is diversified

on the northern quadrant of the village by interesting exposures of other rocks which serve to elucidate the succession of strata immediately underlying the abovenoted Dwárka-limestone beds. The N. of the village is invested by a capping of laterite-conglomerate, overlapped on its eastern moiety by a small, but sharply defined deposit of Gáj (Miocene), limonitic limestones and conglomerates bearing a rich crop of distinctive fossils ; while these in their turn are shown upon the summit of an isolated hillock hard by, to be conformably overlaid by the denuded remains of a compact whitish freestone in flaggy beds, the basal portions of which are crowded with fossil (chiefly lamellibranchiate) shells, which do not tally with those of the Miocene strata below, but clearly belong to a higher horizon ;—the Dwárka Group of FEDDEN.

Geological Structure of the Coastal Borderland near Visawara.

Farther south-eastward, at a distance of about 2 miles, the coastal borderland in the neighbourhood of Visáwára presents a slight but subtle change. The Creek which breaks the continuity of the shore-line SSW. of the town exhibits at its mouth a varied development in the disposition of the strata. It is probable that this inlet dates back to Pre-Pleistocene times, or at all events had an existence prior to the deposition of the miliolite-limestone formations. This is evidenced by the superposition of the beds laid bare by the erosion of the rivulet which terminates in the creek ; for the river-terrace formed by the sub-recent elevation of the land shows its gravelly deposits to be overlaid by from 10 to 15 feet of miliolite forming a bold sea-scarp at the mouth of the creek.

Fringing Coral-reef Boldly Bared at Visawara Creek-mouth.

Underlying the river-gravel, there comes a very conspicuous fringing reef of astræan and other corals, manifestly of Dwárka age, the bulk of which appears to be only partially changed by fossilisation ; albeit the same structure, disclosed by well-shafts inland, reveals the coralla completely re-calcified. This coral-reef is here to be seen *in situ*, as though still growing upon its base of fossiliferous Dwárka-limestone conglomerate, while the underlying beds of the same group are composed of thick compact and flaggy freestone essentially similar to that noted above, as crowning the singular hillock NNE. of Tukra. Inland at Visáwára, the Dwárka beds are worn down to their base at the N. end of the town, and the underlying Gáj, limonitic-limestone outcrops in dominance with a plentiful inclusion of fossil-shells and shell-casts in its rubbly subsoil, extending to the NW., N., NE. and E. of the town.

At the parallel of Visáwára the coastal deposits of Tertiary and subsequently formed strata stretch so far inland, that they can scarcely come within the popular meaning of sea-side structures, although they must thus be included in this place. The Miocene Gáj-limestone deposits, more or less obscured by Dwárka-limestones, outcrop intermittently for more than 2 miles NE., to the site of the ruins of the Hathiáni Temple; emerge again 4½ miles ENE. from Visáwára, NE. of Keseo, overlapping the bedded-lavas of the Deccan trap Period, are continuous most of the way E. and ESE. for 2½ miles towards Pálakra, and thence onward and eastward are obscured by the fresh water alluvial deposits of the Ger or Great Northern Marsh of Porbandar State, to reappear finally on the confines of Bhárwára, or approximately 6 miles distant, 'as the crow flies,' from the present sea-shore.

Inland Tertiary Deposits at the Parallel of Visawara.

These inland outcrops are specially noteworthy by reason of certain economic products which show signs of being worthy of exploitation. As already recorded, they comprise a presumably extensive occurrence, overlying the subsoil, of good yellow-ochre, one mile E. by ESE. of Pálakra, at a depth of about 15 feet from the surface; sundry beds of compact, ornamental yellow limestone called Pindáralite;* and the newly named Bhárwáralite, which is an indurated, fresh cinnamon-coloured, ornamental stone, available in thick and large slabs, 1¼ miles SW. of the village after which it has been named. Of scientific interest in the same neighbourhood, ¼ mile SW. of Bhárwára, the dry bed of the river exposes the presence of a Miocene coral-zone, characterised by the densely crowded stalks of *Stylophora*, a few compound single corals, occasional valves of *Venus cancellata*, and some spires of a *Turritella*.

Economic Products of Inland Tertiary Deposits.

Repetitions, on a less-marked scale, of the succession of strata recorded as occurring at the northern scarp of Visáwára Creek-mouth, are found in irregular development along the whole length of the strip of land between the Visáwára river and the sea-shore, as far as to the SSE. of Rátari; but thereafter, and right down to the north-westward confines of Porbandar City a wonderful uniformity of structure prevails which may be briefly expressed as follows :—

Geological Structure of the Coastal Borderland from Ratari to the N. of Porbandar City.

* 'Memoir on the Economic Geology of Navanagar State,' Bombay, 1914, 177, *et seq.*

Breakers of sound and strong, sandy and shelly thick flagstones, full of brecciated as well as rounded fragments of Gáj limonitic-limestone, outcrop more or less prominently at low-tide mark on the shore-line of the Arabian Sea, to be succeeded by a strip of beach of very variable width. The surface of the land itself commences with dunes of blown sand, composed for the most part of whole as well as comminuted shells, resting upon an almost indistinguishable base of raised beach of the same, but more firmly consolidated composition. Frequently a second more inland, billowy dune obtains, and it is usually through this upraised æolian and partly marine supra-littoral accumulation that pits are extensively dug, all the way from Khimeshwar Temple near Kunchri right up to within a short distance from Porbandar City for a loosely compacted stone, much used for the erection of the poorer classes of dwelling-houses.

Coarse, Loosely-textured, Consolidated Shell-sand, Quarried as Inferior Building-stone, on Shore NW. of Porbandar City.

The Dwárka beds immediately underlying the abovenoted stone, varies in character considerably, as it is revealed either by natural or artificial exposures farther and farther inland;—possibly by reason of altered horizons. They constitute a long low ridge of very rough surfaced shelly and sandy, compact, medium-grained, flaggy limestone which extends continuously from the SSE. of Rátari for no less than six miles towards the Capital-town, and at a mean distance of 4¼ furlongs from the shore-line.

Varied Character of the Dwarka Beds, N. of Porbandar City.

Farther inland, the Dwárka beds assume a very different character and vary very much both horizontally and vertically. From Bardia to Sirinagar and NE. of Kátela they are represented by thin and thick ruddy flagstones, often very rubbly, sometimes concretionary, and interbedded with or overlying considerable depths of conglomerate, especially at the SE. side of Sirinagar, while the beds farther south in the direction of Kátela, are covered by a compact crust of miliolite. Strangely enough, on the NW. side of Sirinagar, the same beds of stone, are compact and cancellated, lie upon a richly fossiliferous base, which in its turn rests upon a rubbly zone of Gáj limonitic limestone crowded with organic remains.

At Kunchri the Dwárka beds yield large white and ruddy flagstones composed of alternating compact finely-textured material in thicknesses of an inch or more, and dark-coloured thin laminæ. These great slabs of limestone sometimes hold together in thick-

Kunchri and Degam Flagstones of the Dwarka Group.

nesses of a foot or more ; but they are only too often prone to part into flakes along their dark-coloured incoherent laminæ. The same stone spreading out over the plains in the direction of Degám, becomes more or less bleached, and is much false-bedded. It is very extensively quarried around and about the smalltown but only to inconsiderable depths, as it speedily grows rubbly, fossiliferous and conglomeratic.

Dark-coloured Flagstones of the Dwarka Group.

Towards Babadeshwar Temple to the N. of Degám another marked change in this variable stone was noted, for it acquires a very dark colour,—sometimes brown, purplish and even almost black ;—and the same kind of alteration in colour also occurs at the isolated hillock called Bhado Dhár, where the false-bedded stone may be seen directly overlying the yellow Gáj-limestone to the SW. of Bhárwára. Another isolated outlier of Dwárka-limestone of a rusty colour, in thin flaggy laminæ of a shaloid character, outcrops in form of a narrow elongated hillock, by the highway about ½ mile S. of the town of Khámbhodar. The surface of the hillock adjoining the roadside is literally riddled with pits ; for the material, which is hard although flaky when extracted, breaks up very readily into an angular shingle of from 1 to 1½ inch gauge, and is unadvisedly used by the State contractors for road-metalling.

Dwarka Beds between the Parallels of Kunchri and Porbandar City.

Between the parallels of Kunchri and of Porbandar City farther south, the really coastal Tertiary and Post-tertiary, or, to be more precise, the Gáj (Miocene), and Dwárka (Plio-Pleistocene) Groups of beds, extend inland superficially for very considerable distances. The false-bedded Kunchri and Degám flagstones, with their underlying quota of fossiliferous conglomerate, spread southward continuously as far as Porbandar City, covered by deposits of alluvium thrown down in the region of the NW. trending backwater from Porbandar ;—upon which the State salt-pans are situated. Towards the east they encrust the ground up to a geological boundary extending from the neighbourhood of Bákharla, slightly E. of Kolikhara, and then in the direction of Ránáwáo and intermittently far beyond. Southward they are obscured by the alluvium of the Great Salt Marsh.

Gaj Beds between the Parallels of Kunchri and Porbandar City.

Underlying the Kunchri and Degám flagstones, which by reason of their hardness and capability of resisting great crushing strain when laid with their laminæ in a horizontal position, are largely used locally for the foundations of dwelling-houses, it is

Plate XXVII.

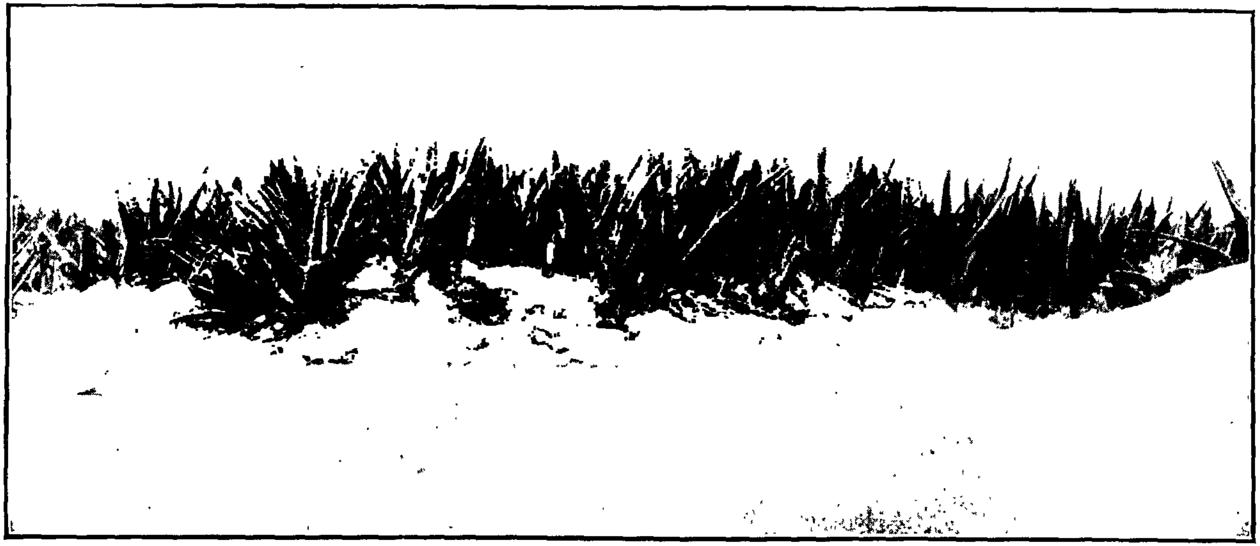


Fig. 29.—Conservation of Coastal Blown-sand.—Thickly clustered growths of the Common or Barbados Aloe, *Aloe vera*, 500 yards inland from the shore at the parallel of the village of Páta. It is suggested that these plants should be cultivated along the seaboard, with the twofold object of holding the blown sand in place and of reaping a revenue from the medicinal crop. From a *photograph* by E. Howard Adye, F.G.S., taken on the 19th April, 1916.

presumed that the Miocene, or Gáj limonitic-limestones, recognisable at a glance by their prevailing yellow and orange hues, also extend far eastward from the coast-line towards the base of the Barda Group of hills in the direction of Ránáwáo and beyond. Evidences of this are to be found as follows :—(i).—The coast-line breakers at low-tide mark contain an abundance of both rounded and angular fragments of these unmistakable stones. (ii).—The Creek-banks on the N. and E. sides of Porbandar City show small exposures of shelly and sandy Dwárka-limestone, overlying Gáj limonitic-limestone. (iii).—The new large well-shaft, within the Bokhira limit near the Porbandar City water-works exhibits beneath a layer of ruddy, indurated Dwárka-limestone, a thick deposit of beds of compact, Gáj limonitic-limestone of the Pindá ralite type, and richly fossiliferous rubbly conglomerate belonging to the same Group. (iv).—The erosion of the Wandána Vokala at Virpur by the high-road to Ránáwáo shows the yellow Gáj-limestone gleaming beneath surface beds of Dwárka-limestone on its E. bank. (v).—The miliolite deposits encrusting the plains and deeply developed towards the base of the Barda hills, when examined under the microscope, exhibit a fairly large proportion of rounded grains of Gáj limonitic-limestone, detectable by their characteristic fossil contents and lithological peculiarities, which will be exemplified in the sequel by photomicrographs.

Miliolite Deposits Eastward of the Geological Boundary of the Gaj and Dwarka Beds at the Parallel of Porbandar City.

Eastward, beyond the geological general boundary of the Gáj and Dwárka beds, which occasionally outcrop as insignificant patches here and there, the country-side is practically encrusted with miliolite deposits, already ascribed to a much later period of the Pleistocene Age. Deposits of coarse, sandy and much honeycombed, weather-worn and decomposed or altered miliolites, from a few inches up to ten or twelve feet or so, obtain in undenuded areas, from the coastal borderland of Porbandar City to be swept almost entirely away from the surface of the Dwárka beds, until about three miles or thereabouts from the base of the S. and SW. Bardas. The surface of the ground thereafter becomes more and more thickly strewed with miliolite drift and fragments of the mountain massives, while the deposits of the limestone gradually increase in thickness up to the line of limitation on the Ádatiána Heights.

Porbandar City, with its encircling Creek which swerves south-eastward to pass into the NW. diverticulum of the Great Salt Marsh, furnishes another well-defined break in the continuity and character of the geological coastal borderland of the State ; for it is at this juncture

that confusion is apt to arise concerning the origin and succession of the Quaternary strata which constitute the main portion of the shorelands. A few of the observations in this connection must therefore be taken as provisional pending the confirmatory evidence of forthcoming laboratory research.

Dwarka Flagstones of Chaya and its Surroundings.

There can be no room left for doubt, that the Dwárka flagstones, laid bare by the wearing down of the miliolite towards the SE. of Porbandar City and partially obscured be recent deposits of marsh mud, increases both in thickness and economic quality on the way to Cháya ; for the town there rests, as shown by local well-shafts, upon a deep foundation of thick, compact, but variable beds of the flagstones which, however, by reason of their superior hardness, liability to split along false-bedded rifts, and the comparative difficulty experienced in extracting and tooling the stone, have been only sparingly utilised. These Dwárka flagstones, veiled by alluvial deposits, reappear on the W. and especially upon the SW. and S. side of Cháya, to constitute the basal fabric of a high ridge which runs practically parallel to the shore-line at a mean distance of a trifle over half-a-mile therefrom, and rises to a maximum height of 66 feet above the level of the sea. The flagstones, however, do not take any further part beyond its foundation in the formation of the ridge, but pass sheer beneath that structure to reappear first upon the leeward side of the blown-sand dunes, and afterwards as breakers beyond the strip of beach at low-tide mark.

Sub-aerial Origin of Chaya-stone, as Fine, Consolidated Blown-sand.

At first sight, the stone forming the abovenoted high ridge presents a strong miliolitic facies ; but there are subtle differences, tacitly granted by even the native quarrymen, which serve, to separate 'Cháya-stone,' as it is called, from the *dorá-páná,* miliolite or 'Porbandar-stone' of commerce. Laboratory analyses and optical determinations will doubtless serve to define the differences that subsist between the two textures, and to confirm the opinion that the Cháya-stone consists essentially of a sub-aerial consolidation of fine blown-sand, of sub-recent date, representing a former dune which has acquired its present inland position through the elevation of the land.

The Chaya-stone Quarries SE. of Porbandar City.

Situated approximately ¾ mile SSW. of Cháya, the highest part of the ancient, solidified dune of fine blown-sand has, since about 50 years ago, been made the centre of an extensive series of pit-quarries, which to-day present the appearance of a

range of huge oubliettes, many of which are excavated to the depth of about 60 feet. These strange-looking, champagne-bottle shaped burrows may be very simply accounted for by the fact that they were commenced as small vertical shafts through a surface layer of much perforated and then of rubbly stone, which at depths of from 10 to 20 feet, gradually becomes more compact and commercially valuable; so that, in order to save labour and expense, the native quarrymen began undercutting, or, in reality mining on a small scale, leaving a pillar or two here and there to avoid collapse—occasionally, however, without avail.

Causes of Perforations in the Chaya-stone.

The superficial portions of the Cháya-stone are much honeycombed and indurated by sunbaking, except at sundry denuded places, and are therefore rejected by the quarrymen; but their perforations appear to differ in character from those found in corresponding situations of the miliolite, and are usually, especially at depths of 10 or 12 feet, when diminished in dimensions, filled with cores of ruddy clay and possibly vegetable remains. It is therefore assumed, subject to laboratory corrections, that the perforations and other larger interspaces, represent the relics of former binding weeds and creeping plants which formerly flourished on the original dunes of sand, coupled with the sporadic burrows of agamoid lizards, such as abound on the sandy stretches at the lee side of the sand-dunes bordering the beach of the entire length of the State shore-lands.

Structural Peculiarities of Chaya-stone.

Cháya-stone, as already intimated, varies in texture and quality both horizontally and vertically, but not to the same marked degree as stones of marine-littoral origin such as the underlying Dwárka flagstones or the miliolite. While its superficial layers are indurated and honeycombed by the combined agency of plant-growths and weathering, the texture of the material appears to be uniformly fine-grained. Deeper down, while the texture remains practically unchanged, the perforations diminish in size and are more or less occluded by incoherent as well as compact ruddy, earthy matter, probably representing successive buried layers of plant-roots and creeping-rhizomes. At the lowermost zone, some 50 to 60 feet below the surface of the deepest developments, the stone once more assumes a much cancellated but somewhat varied texture; presumably by reason of its original partially sedimentary character when deposited as beach-sand upon the gradually uprising substratum of Dwárka flagstones.

Market Value and Uses of Chaya-stone.

At sundry favoured places, the Cháya-stone is more or less free from perforations and becomes quite compact and of fairly white colour, closely resembling a good-grade miliolite; but, as it is the custom at these quarries to merely recompense the workers for their labour, all qualities are sold without distinction at the various pit-mouths by bargain. The stone is usually cut into rough blocks 12 by 12 by 6 inches in dimensions and normally sold at about Rs. 5-8 per 100 blocks ; other sizes are available by special orders at proportionate prices, but are only seldom demanded. Trade statistics are not registered, as the demand for the stone is entirely local ; although as many as 25 pits are kept open during the working season to supply calls from Porbandar City-builders for the erection of native houses and cottages.

Consolidated Blown-sand of Mithi Khan, full of the Valves of Recent Sea-Shells.

Descending on the southern side of the Cháya-stone sites, a small valley is formed by the rising of another but much less lofty elevation, which also runs intermittently parallel with the sea-shore at a mean distance of 2½ furlongs therefrom. This ridge is manifestly the solidified representative of another but more recently formed dune of blown-sand and was formerly quarried for stone at a site called Mithi Khán, whence material of a less coherent character than that of the Cháya-stone was extracted for local needs. The stone, which is likewise freely cancellated, bears large numbers of partially altered shells of marine molluscs chiefly of Recent *Pelecypoda*. The consolidated, blown, shelly-sand of this ridge overlaps the underlying strata of Dwárka flagstones which outcrop at its windward base, like a long line of upraised beach.

'Natural Chunam' on the Leeside of the Shore-dunes, S. of Chaya.

Yet another depression here intervenes, which during the monsoons is flooded with water and separated from the open sea by a third ridge of blown-sand constituting a stretch of dunes in process of formation ; which if the elevation of the land continues, must eventually give birth to a third terrace of consolidated stone of the Cháya type. The abovenoted depression at this particular place is specially interesting and of some importance locally as a site from which poor persons are allowed to dig for supplies of 'natural chunam.' The carbonated waters draining the highly calcareous ridges to the NE., annually dissolve large quantities of lime and bring it down to the channel below to be first precipitated by subsequent evaporation and then naturally kilned by the agency of sunbaking.

PLATE XXVIII.

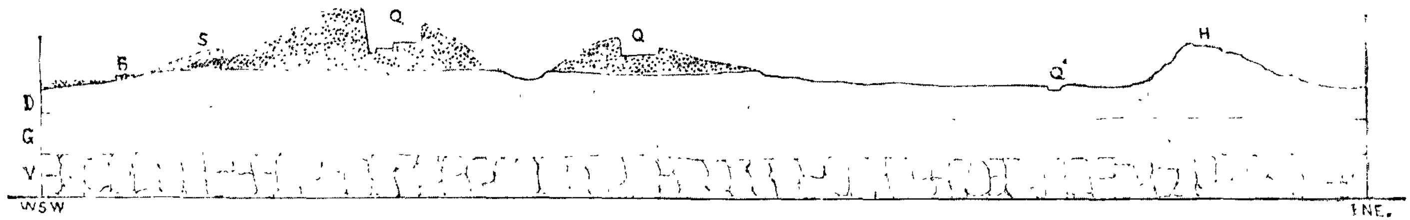


Fig. 30.—Diagrammatic Section to show *the Geological* Structure *of the* Coastal Borderland from WSW. to ENE. between the Parallels of Madhavpur and Mulmadhavpur. **V.**—Volcanic rocks or Bedded lavas of the Deccan trap Period. **G.**—Gáj (Miocene) Group of Beds. **D.**—Dwárka (Plio Pleistocene) Group of Beds, showing exposure of 'Breakers,' **B.**, at low tide mark. **S.**—Shoreland sand dunes. **Q., Q.**—Quarries in consolidated blown sand of raised dunes. **Q'.**—Quarry called Veler Khán, in coarse, sandy and shelly Dwárka limestones. **H.**—Hillocks of false bedded Dwárka flagstones.

On the windward side, the shore sand-dunes slope downward to form a variable width of sandy shell-strewed beach, from which the underlying strata of Dwárka flagstones emerge at low-tide mark, as usual along the whole of the coast-line from Porbandar City, to form a bold line of breakers. Towards the N. of Cháya, the Dwárka flagstones persist until temporarily obscured by the alluvium or waters of the Porbandar Creek to be capped at the eastward bank of the latter by a very thin denuded deposit of decomposed miliolite.

Probable Deposit of Fine Miliolite on the slope of Salak Tobra near Adodar.

Contrary to all expectations, in following the south-eastward course of the Cháya ridge of consolidated blown-sand, that eminence gradually dwindles down to rise again to the still greater height of 96 feet above the level of the sea in the direction of the small town of Adodar, (pronounced Aorda), where it is known by the name of Sálák Tobra ; but Sálák Tobra is no longer formed from blown-sand, being constituted from base to summit of much false-bedded and deeply decayed Dwárka flag-stones ; on its eastward slope however, $\frac{7}{8}$ mile NW. of Adodar, the hill supports a fairly thick deposit of a finely-textured white limestone, strongly resembling a high-grade miliolite of the best quality ; but upon being handled the stone was found to break short when sliced to the tenuity of $\frac{1}{4}$ inch, whereas good miliolite can be cut almost to the thinness of a wafer without falling to pieces. Clearly then, this stone if it turns out to be a miliolite, *i.e.*, a true sedimentary stone of marine origin and Pleistocene Age, must be very peculiarly constituted. What the natureof that constitution really is, remains to be shown by forthcoming laboratory determinations. Meanwhile, it appears to be just possible that the stone is a true miliolite, from the circumstance that at aboutthe same parallel and only a trifle over two miles inland, a small hillock, 56 feet above the sea-level, called Chirora-ka-Tobra rests upon a base of Dwárka flagstones surrounded by the alluvium of the Great Salt Marsh, and is apparently built up of much false-bedded, finely laminated limestone so much decomposed as to be on the very verge of dissolution.

Geological Structure of the Coastal Borderland at the Parallel of Adodar.

At Adodar itself, $\frac{1}{2}$ mile NW. of the town, the Dwárka flagstones, which evidently constitute a permanent feature of the coastal selvage are covered by a deep dome-shaped eminence of finely-textured, perforated and false-bedded, soft grey-brown stone of the Cháya type, and, like the latter, is very probably of æolian origin. This was formerly quarried to a maximum

depth of 20 feet. Otherwise the geological structure of the coastal borderland at this parallel and right down SE. along the shore for fully $3\frac{1}{2}$ miles to the neighbourhood of Tunkra, is essentially similar to that of Cháya, and might be correctly exemplified by an abbreviation of the same sectional diagram.

Inland, however, the Dwárka beds of Adodar, present a varied group of rubbly, concretionary, russet-coloured stone, interbedded with thin flagstones passing into richly fossiliferous conglomerates below ; and these beds outcrop, often at a large angle (on account of their false-bedding), to render the country roads exceedingly rough and rutty, for nearly a mile and a half inland, after which they are covered bý the alluvium of the Great Salt Marsh, the main body of which roughly represents the enormous total of more than 60 square miles of reclaimable waste territory.

The Northern Moiety of the Great Salt Marsh.

Between the parallels of Cháya and Adodar, the inland geological structure of the country is to a large degree obscured by the alluvial deposits of the main-body of the Great Salt Marsh, which at this,—its northmost moiety,—has an average width of a little more than 4 miles ;—a dreary, barren waste of dark-grey mud passing into the condition of saliniferous clayey earth during the dry season, but flooded by the rains to the depth of many feet. The elevation of the land, which has been steadily progressing since the deposition of the miliolite in Pleistocene times, has already reclaimed considerable tracts of this periodically submerged land, and the deposits of alluvium, usually deep enough for all agricultural purposes, and capable of being prepared almost without digging or ploughing, is acclaimed by native husbandmen to be wonderfully fertile, especially in germinating power and for the rapid growth and maturing of cereal crops.

Geological Landmarks fixed from Mokal as a Centre of Observation.

Patches of stony ground, notably to the south of Rángháwáo, around Khokhri Parab, the hillock of Chirora-ka-Tobra and midway on the track to Mokal, serve to reveal the continuance—right up to the westward confines of the last-named village—of Dwárka beds of rubbly flagstones. To the N. of Mokal, where the strata are not covered by alluvial deposits, the ground gradually shows outcrops of bedded-lavas ; but these soon become strewed over with miliolite drift, and are finally covered more or less deeply by basement beds of miliolite-conglomerate and coarse miliolite on approaching the district town of Ránáwáo. Slightly eastward from Ránáwáo, the miliolite

deposits are completely worn away at places to reveal false-bedded outcrops of medium-grained Dwárka flagstones.

Eastward of Mokal, the alluvium, still distinctly saliniferous, but augmented by detrital matter from the northern uplands, is in like manner gradually ousted from the surface, first of all by outcrops of bedded-lava and then by a deposit directly upon the latter of basement beds of obliquely laminated miliolite, right up to the boundary of the State, *viâ* Bápodar to the relics of old Asiáwadar. Practically the same conditions prevail NE. to Wadwála, and to the boundary district-town of Kandorna, a little beyond which across the River Minsar the ground becomes essentially volcanic;—here, Dhának Dhár, an outlier of hypabyssal rock, rises to the height of 137 feet above the level of the sea.

Geological Structure of the Shorelands to the N. of Tunkra.

Returning to the region of the shorelands of the State, a great gap in the continuity of the coast-line occurs about 5 furlongs NW. of the village of Tunkra, whereby a formidable inlet of about ½ mile broad remains patent to the open ocean during the rainy seasons, but is closed by a sandy-bar at other times. The effect of this break upon the geological structure of the coastal borderland has been to cause the stretch of low hillocks trending SE. from Adodar at a mean distance of 800 yards from the sea, to swerve slightly inland on both sides of the breach. The NW. extremity of this wide creek is much attenuated, and thereby affords a good crossing over a stone causeway which, when the monsoon floods subside, serves as a temporary dam to retain a considerable body of brine on its landward side, and the brine thus conserved forms a kind of pan from which evaporated salt is collected.

Evaporated Sea-salt and the Salt-pans of Porbandar State.

While touching upon the subject of salt, it will be remembered that a passing allusion was made to the salt-pans located about a couple of miles NNW. of the City of Porbandar, on the east bank of the backwater, from the working of which a small revenue accrues. With reference to this matter, the following brief sketch, taken from the writer's Rough Monthly Reports, may here be advantageously repeated:—"Alluvial deposits obscure the bed of the backwater in the region of the salt-pans; but from observations of outcrops on the roadway north-westward from Bokhira it is at least certain that the underlying strata belong to the Dwárka Group of beds, equivalent with those that stretch NW. to the confines of Kunchri and N. to Degám.

The salt-pans are projected after the fashion of native wheat-fields, into a number of rectangular beds or shallow tanks, divided by channelled mud-banks or aqueducts; and the brine from the back-water is collected at high-tide into a well-shaft or reservoir adjoining, from whence it is raised as required by leathern buckets and bullock-labour, to be allowed to flow by gravitation into the prepared pans. Evaporation by the fierce rays of the sun does the rest; and, so soon as a sufficiency of salt has been precipitated, usually in caky layers of about an inch or two in thickness, it is simply gathered by handfuls, rinsed in the remaining brine and thrown into small heaps to be gathered for the market."

Estimation of Magnesium Chloride in the Evaporated 'Mother-liquor' of the Porbandar Salt-pans.

"Samples of the salt as well as of the mother-liquor were taken for analyses, with a view to determining whether it would be possible to profitably purify the former, or utilise the latter for the separation of magnesium chloride." Now, it is well known that when sea-water is evaporated, gypsum or the hydrous sulphate of lime is precipitated as soon as 37 per cent. of the water has been driven off; but that the common salt or chloride of sodium remains in solution until 93 per cent. of water has evaporated. Again, the chloride of magnesium being more soluble than common salt, would naturally remain in much larger proportion than before in the residual mother-liquor; so that when a sample of the mother-liquor, taken from the Porbandar 'Salt-pans,' was analysed*, it was not surprising to find that at a specific gravity of 1·300, no less than 23.3 per cent. of magnesium chloride, equivalent to 48·6 ozs. per gallon, was estimated in the sample. It may be recorded that DR. DITTMAR'S generally accepted estimation of 10·878 per cent. of magnesium chloride, in normal sea-water,† proves that the quantity of that salt in the sample under consideration is unquestionably very high. Unfortunately, however, the insuperable difficulty that would be experienced in securing sufficient supplies up to standard of the sample, coupled with expensive technical processes and outlay for the installation of a costly plant, would render any project for the separation of the salt on a commercial scale, extremely hazardous.

Geological Structure of the Coastal Borderland at the Parallel of Tunkra.

At the parallel of Tunkra, the comparatively low-lying shorelands, rise to a maximum height of only 44 feet above the sea-level, about $\frac{1}{5}$ mile SE. of the village; but the succession of the strata, although in no-wise different in character or kind from

* By R. E. J M'CULLY of the Porbandar Cement Works, on 11th February 1916.

† *Report of Voyage of the Challenger*, 'Physics and Chemistry,' Vol. I, 1884.

that already noted to prevail on the north, are so deeply developed immediately beneath and on the west side of Tunkra, as to become commercially important. The compact shelly and sandy Dwárka flagstones, containing abundant clastic fragments of Gáj limonitic-limestone, form unusually thick beds of compact, more or less uniformly textured material suitable for general building purposes, but have only been sparingly extracted on the WSW. side of the village for local needs.

Alluvium of the Great Salt Marsh, E. of Tunkra.

Eastward from Tunkra, the Great Salt Marsh is encountered within a mile from the village, and extends for more than 6 miles in an unbroken waste, during the dry season, of saliniferous-alluvium to depths of from a few inches to many feet. This alluvium, in a more or less pulverulent condition, if freed from an excess of salt, would instantly be converted into an ideal agricultural soil; as demonstrated by the fertile stretch of alluvial land eastward of the marsh up to the boundary of the State. A gradual reclamation of the land in this locality by natural causes, however, is most unfortunately subject to seasons of drought; and, during the monsoon, to floods; which prevent the land from being cultivated for more than a very few months during each year.

Suggestions for the Reclamation of Land from the Great Salt Marsh and Preliminary Irrigation Proposals.

Suggestions for the reclamation of this vast tract of country-side have been recorded in the narrative portion of these reports; but it may here be additionally noted that pending the installation of a comprehensive system for the conservation of surface drainage coupled with irrigation works, much immediate good might be done, by the use of a prospecting drill, to sink a few artesian well-shafts in the neighbourhoods where water is most needed during the dry season. The enormous discharge of freshwater into this region of the Great Salt Marsh has also been fully treated of in the narrative reports.

Geological Structure of the Coastal Borderland at Gosa.

Farther SE. along the coast-line, at the parallel of Gosa; while the continuity of the Dwárka beds along the seashore remains unbroken, although once more reduced to a less valuable and more distinctly flaggy condition, the blown-sand of sub-recent times appears to have invaded the borderland and become sub-aerially consolidated around and about the village site to considerable depths, giving rise to a thickness of from 6 to 10 feet, of a finely-textured grey-

brown, soft stone, closely resembling good miliolite that has undergone partial decomposition. This stone has been largely extracted for local State use on the S. side of the village, but is not of sufficient importance to be worked for commercial purposes.

Inland from Gosa, somewhat similar conditions prevail as at the parallel of Tunkra ; for the town of Bhád, from which the Bhádar River, —the largest and longest watercourse in the Province of Káthiáwár,— takes its name, lies upon a deep substratum of alluvium which once formed a part of the Great Salt Marsh, but has risen to its present elevation of over 30 feet above the sea level during comparatively recent times. The land, for about a couple of miles east of Bhád, to the State-boundary is also essentially alluvial but overlies a thin stratum of Dwárka Group deposits, which in their turn overlap the bedded-lavas of the Deccan-trap.

During the dry season, Bhád in common with all the neighbouring villages, N., S. and E., suffers severely for a lack of fresh, potable water ; for, although the River Bhádar scarcely ever runs dry, its waters near by Bhád, and far beyond, are almost briny ; while well-shafts, when sunk to the depth of more than 10 feet, also yield brackish water. Well-shafts, however, have not hitherto been sunk to greater depths than 30 feet or so, and certainly not so deep as to penetrate the bedded-lavas ; hence it is very likely that an unfailing supply of fresh water would be obtained by the sinking of artesian shafts hereabouts.

Geological Structure of the Coastal Borderland between the Parallels of Gosa and Navibandar.

Towards the SE. of Gosa, the deposits of consolidated blown-sand accumulate to form an eminence overlooking the village of Nawagám otherwise called Rájpura, where the soft stone is also quarried for local State use. The upper layers of stone in the small pit-quarry are somewhat perforated and resemble the material of a similar origin, excavated on a large scale at Cháya ; but, at a depth of about 12 feet from the surface, the stone changes in character, being composed almost entirely of small and comminuted fragments of recent shells.

Between Gosa and Navibandar, a distance of about 4½ miles, there a decided depression of the shorelands, which slope down from 33 to 13 and finally to only a foot or two above the sea level on the northern side of the great creek into which the River Bhádar flows. The general geological structure of this tract of land has been given in detail in the Narrative Reconnaissance Reports ; but it may additionally be observed in this place that the flat agricultural patch which extends inland for

over a mile and includes the village of Sikása to the N. of the mouth of the River Bhádar, shows a deposit of recent alluvium, overlying about 3 feet of limy and gravelly conglomerate crowded with the remains of recent shells, resting upon a base of compact flagstones of the Dwárka Group ; and this succession appears to be continued for more than 5 miles inland, beneath and beyond the small mud-built town of Garej, a trifle over 2 miles from the boundary of the State. The Great Salt Marsh at this place moreover becomes abruptly constricted to a narrow band of about half-a-mile in width, along which the bifurcated channel of an effluent runs into the mouth of the River Bhádar, ¾ mile ENE. of Sikása.

Geological Structure of the Coastal Borderland from Navibandar to Pata.

At Navibandar itself, the wide creek of the Bhádar, instead of affording a good harbour, takes a NW. course, parallel with the shoreline and is cut off from the open ocean by a narrow bar of sand-covered rock, with but a shallow outlet towards its central part. The geological structure of the coastal borderland from the south of the town for a distance of about 15 miles down to the neighbourhood of the village of Páta, continues constant, without any appreciable irregularity and may be typified by the natural exposures around and about the sea-side town as follows :—A strip of sloping beach of variable width is bounded at low-water mark by large breakers of compact, hard arenaceous and shelly flagstones of the Dwárka Group ; while a considerable space inland is covered by sand dunes of variable heights ;—35, 24 and up to 43 feet above the sea level, respectively, near Navibandar, Balej and Páta.

Inland, at a mean distance of about ¾ mile from the coast, the Dwárka Group of beds rises to form a more or less continuous ridge of hillocks ; which, in the neighbourhood of Balej and southward are succeeded by a subsidiary subparallel ridge, slightly farther inland ; while from thence eastward, to the boundary of the State, about 4 miles distant, the strata are practically obscured, except at sundry patches and inconspicuous elevations, by deposits of alluvium ;—vestiges of the former bottom of the Great Salt Marsh, which must, at one time, have extended over the whole of the southernmost districts of the State, right down to Mádhavpur and beyond.

At the parallel of Navibandar, to the south of the River Bhádar, the Great Salt Marsh still covers a very considerable area,—practically of about 8 square miles of waste ; and this barren tract is prolonged

southward by a strip of about 1 mile broad by 5 miles long to the northern confines of the town of Balej.

The geological structure of the whole of the country-side from Navibandar to beyond Mádhavpur, and from the coast-line to the inland boundaries of the State, has been recorded in detail in the narrative portion of these reports ; so that it now only remains to draw attention to a few noteworthy observations made by the way, which may eventually turn out to be of either local or general economic importance.

Geological Importance and Modes of Distribution of Blown-sand over the Coastal Borderland of Porbandar State.

Attention has been directed to the conspicuous part taken by the blown-sand of the seascape (and the way in which the dunes thus formed are held in place by the agency of plants), in preventing an undue devastation of the coastal borderland. It ought therefore to be both interesting and useful to learn precisely how and by what means, the land in this part of the Province is conserved ; and fortunately, a series of typical examples are available in the neighbourhood of Navibandar as follows :—

Principal Plant-agents Concerned in the Conservation of the Sand-dunes of Porbandar State.

(*i*).—Bordering the beach and but seldom more than 100 yards or so inland therefrom, the sand is frequently held firmly together by the strong underground stems of the beautiful purple-belled perennial creeper, *Ipomœa biloba*,—the *Convolvulus Pes-capræ* of ROXBURGH,—which, by forming a powerful network a few inches below the surface, serves to keep the sandy surface practically flat and level. Associated with this plant, especially at the edges of the low scarp immediately above the beach, may be usually found tufts of the strongly rooted wiry grass *Halopyrum mucronatum* ; and both of these, in days of drought, furnish fodder for camels, goats and even sheep and kine.

(*ii*).—The sand naturally slopes down for a few feet, immediately on the leeward side of the lines of growth abovenoted ; but is re-arrested for from 100 to 200 yards or more, by close growths of sedges, chiefly of *Cyperus stoloniferus*, *C. rotundus* and kindred species, which bind the surface of the sand into a succession of miniature mounds and short ridges of but a few inches in height, yet quite sufficient to prevent very considerable quantities from being blown much farther inland.

(*iii*). Farther inland, most of the remainder of the free sand is caught up by small clumps of shrubs, and retained *in situ* as mounds of larger dimensions than those formed by the sedges. From a distance

PLATE XXIX.

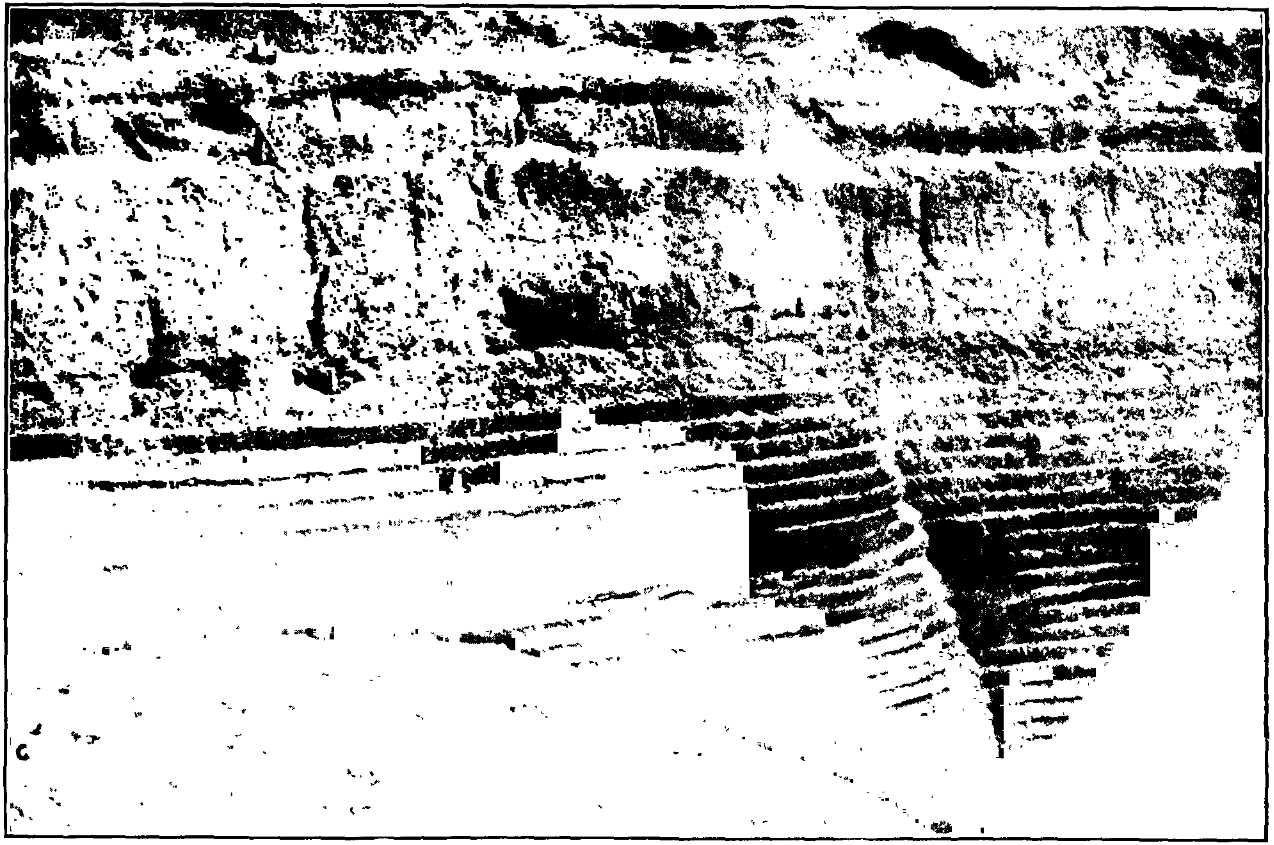


Fig. 31.—Excavations at Babudi Khan, ½ mile ESE. of Madhavpur. A. About ten feet of semi-consolidated blown sand at the top of the quarry back. **B.** From 20 to 24 feet of tolerably compact consolidated blown sand, cut out into building blocks 18 by 12 by 6 inches. **C.** Mound of wastage. From a *photograph* by E. HOWARD ADYE, F.G.S., taken on the 17th April, 1916.

these closely crowded mounds might well be mistaken for a flock of sheep. Near Navibandar, they are chiefly produced by growths of the rubiaceous plant *Hydrophylax maritima* sometimes mixed with bushes of the ubiquitous wild jujube, *Zizyphus nummularia* ; while still farther inland, where only a very spare deposit of blown-sand remains, it is commonly held together by growths of the acanthaceous herb, *Lepidagathis trinervis.* At other places, notably near Miáni, the *roches moutonnées* appearance of the blown-sand is principally caused by close growths of two or three species of *Heliotropium*—*H. ovalifolium* and *H. indicum* being of the most common occurrence.

(*iv*).—Quite local in its distribution, but nevertheless serving to bind the surface of the blown-sand very solidly together, over considerable areas, wherever it once takes root, the common or Barbados Aloe,—*Aloe vera,*—occasionally grows wild upon the dunes of the sea-shore, especially approaching Porbandar City and near the village of Páta.

Stone Derived from Sub-aerially Consolidated Shell-sand.

Sub-aerially consolidated sand of sub-recent and recent formation furnishes material for a very large and important but strictly local industry in Porbandar State. From the lower levels of the slowly elevating beach, the loosely porous stone, composed almost entirely of comminuted shells of marine molluscs, held together by a variable proportion of secondary lime, is very extensively quarried along the sea-shore from Porbandar City north-westward for about 4½ miles to within a stone's-throw from Khimeshwar Temple near Kunchri ; while although similar material unquestionably exists in the same horizon, all along the coast-line, it has only occasionally been excavated and utilised at other places, on a subordinate scale ;—as at Mithi Khán near Cháya, on the SW. side of Chingaria, and about 200 yards SSW. of Páta.

Stone Derived from Consolidated Blown-sand.

When, however, the finer particles of sand* are wafted inshore by the sea-breezes to form a succession of dunes, and the latter gradually come to assume more or less inland sites, it frequently happens, according to the age of the structure, that either its lowermost layers or the entire fabric from base to summit becomes transformed into more or less compact stone ;—and nearly always of a tolerably fine texture. Numerous examples of these sub-aerially consolidated

* Not necessarily grains of quartz, but composed mainly of calcareous organic remains.

blown-sands are to be met with along the region of the coastal borderland of Porbandar State, and have been duly registered in their proper places in the pages of the Narrative Reports. A few of the more commercially valuable of these may nevertheless be grouped together in this summary in the order of their importance as follows : (*i*).—Cháya-stone, directly overlying the beds of hard, sandy and shelly limestones of the Dwárka Group ; very deeply quarried for building-blocks, about 2¾ miles SE. of Porbandar City. (*ii*).—Mádhavpur-stone, extensively quarried for local use only, in the neighbourhood of the sea-side town, from the ancient consolidated sand-dunes there situated. (*iii*).—Gosa and Nawagám-stone, desultorily extracted for State use. (*iv*).—Other minor sites only occasionally drawn upon at Adodar and Páta. None of these, with the exception perhaps of the most compact variety of the Cháya-stone, are sufficiently useful for building purposes to justify more than strictly local cartage expenses.

Road-metalling Materials for the Southern Districts of Porbandar State.

Finally, with reference to the southern districts of the State, namely, from Porbandar City to Mádhavpur the problem of how to supply high-grade materials for road-making, at small initial cost, is an unusually difficult one to solve. For the City itself, an abundant supply of the highest possible grades of road-metals is fortunately available at reasonable rates, by means of existing railroad facilities from the main quarry sites near Ránáwáo. The northern districts of the State, if not quite so advantageously situated, can nevertheless be fairly well catered for from a few tolerably large and far-reaching volcanic dykes and some of the more compact bedded-lavas through which the dykes are thrust ; but the southern moiety of the State, with the exception of its remote north-eastern portion does not contain any material harder or more durable than sundry zones of highly arenaceous limestones of the Dwárka Group, which, of course, rank quite low in the attrition-test scale of road-making stones.

Obviously, the highest-grades of macadamising material would, in the long run, also be the cheapest that could be used ; but, in order to minimise immediate transport expenses, the next best thing that could be done would be to utilise the most durable of local materials. These comprise :(*i*).—The hard and compact varieties of arenaceous and shelly Dwárka-Group limestones, miscalled *kálá-paná* or "black-stone," which occurs in the form of large blocks or breakers at low-tide-mark all along the coast-line, and is re-exposed at a mean distance of about 2 furlongs inland in positions suitable for excavation. (*ii*).—Another

PLATE XXX.

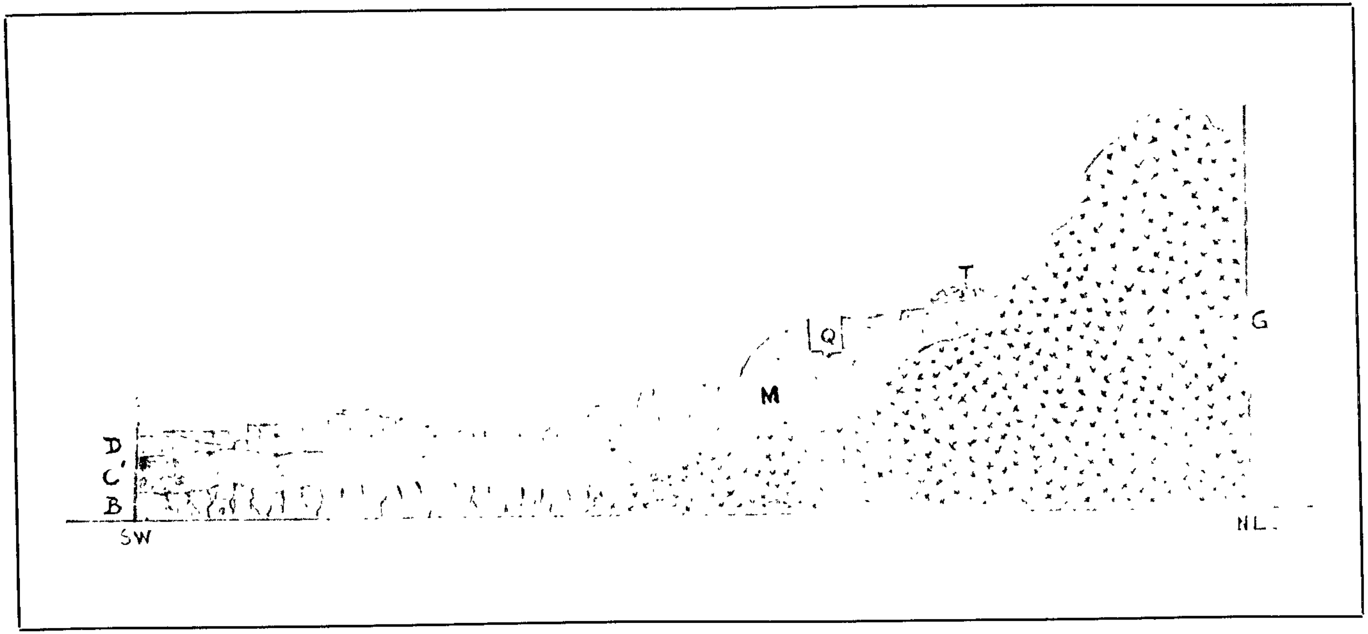


Fig. 32.—**Diagrammatic Section from SW. to NE., through the Region in the Neighbourhood of Adatiana at the base of the Barda Group of Hills.** **G.**—Hypabyssal Rocks of the Mountain-massive. **B.**—Bedded-lavas. **G'.**—Gáj Group of Beds. **D.**—Dwárka Group of Beds. **M.**—Miliolite-limestone. **Q.**—Quarry sites on Ádatiana Heights. **T.**—Moranoid talus of Blocks and Boulders detached from the Mountain-massive above and obscuring the Miliolite at the Limestone-limit.

variety of apparently azoic, arenaceous flagstones, much false-bedded N. by NNE. of Rabárikhira near Balej, and in somewhat different but more extensive development forming groups of ridge-hillocks to the S. and SSE. of Mulmádhavpur; and a fossil-bearing zone of the same stone excavated from shallow surface pits, called collectively the 'Veler Khán,' ½ mile E. and also ½ mile N. by NNE. of Mulmádhavpur. (*iii*).—A buff to ruddy, rubbly, sometimes conglomeratic and concretionary zone of indurated, sandy limestone, likewise belonging to the Dwárka Group of beds, found in good workable exposures underlying the small town of Adodar; on the NE. slope of the ridge of hills ESE. of Páta; at the surface 1 mile SE. of Mander; and from Babudi Khán 1,000 yards or so NE. by ENE. of Kadach.

FINAL QUARTERLY REPORT

ON

THE ECONOMIC GEOLOGY OF PORBANDAR STATE

BY

E. HOWARD ADYE, F.G.S., etc.

Director, Geological Survey of Porbandar State.

March, April and May, 1916.

Location of the Oldest Rocks in Porbandar State.

REFERRING BACK to the oldest rocks encountered in Porbandar State, namely, the Earlier Eruptives or Bedded-lavas of the Deccan-Trap Period,* the approximate situation of the areas characterised by their outcrops, is shown upon the geological chart accompanying this report, by a flat green tint ; while the dykes belonging to the same series as well as those pertaining to the later period of volcanic activity are indicated by long red lines to mark their courses across the countryside.

The Bedded-Lavas of Porbandar State.

There can be no room for doubt that the bedded-lavas of Porbandar State, in common with their counterparts covering by far the largest portion of the Province of Káthiáwár, were formed by successive effusions of molten matter from numerous elongated vents or fissures in the earth's crust,† and that their history dates back to Cretaceo-Eocene times ;‡ but, as the principal problems which call for consideration in this connection are concerned with matters of commercial importance rather than of scientific interest, it must at present suffice to afford a brief description of the general structure and mode of occurrence of these lava-flows for the guidance of prospectors in quest of economic products.

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* *Ut supra*, pp. 19, 20.

† "Memoir on the Economic Geology of Navánagar State," by E. Howard Adye, Bombay, 1914, pp. 26, 27.

‡ *Op. cit.*, pp. 51, 52.

Each consolidated bed of lava, which may vary from less than six to ten feet as a rule, but sometimes reaches to as much as from fifteen to twenty feet in thickness, may be roughly divided into three zones, which usually pass insensibly into one another, *viz.* :—

Bedded-Lava Zones.

An upper, exposed or superficial layer of inconsiderable thickness, characterised by a rough crust, frequently bearing volcanic ashes, ejectamenta or scoriæ, and therefore called the *scoriaceous zone* ; but also holding innumerable steam-created vesicles, and hence, likewise known as the *vesicular zone.* These vesicles usually assume elongated shapes by reason of congelation during the flow of the still molten mass, and become more or less almond-shaped ; so that when they are afterwards filled or partially filled with secondary products, the lava is said to be *amygdaloidal.** The contents of these vesicles, or *amygdales,* may be derived by infiltration from without or by internal segregative changes ; and by reason of their varied composition, colours, contours and distribution in the substance of the rock, frequently endow the latter with an ornamental character.

Amygdales and Geodes.

Although no 'hard and fast' rules can be laid down about the shapes, sizes and arrangement of amygdales in lava-flows, it may be stated that while the most superficial portions of the amygdaloidal zone usually exhibit almond-shaped vesicles, the latter generally show a tendency to become quite spherical a trifle deeper down ; and, upon approaching the lower or compact zone, assume altogether irregular shapes and are less frequently formed. When the amygdales exceed an ordinary almond in size, they are commonly called *geodes* ;† and geodes which occupy larger spaces than those likely to have been produced by steam, may frequently assume gigantic dimensions within these lava-flows of the Deccan-Trap Period.

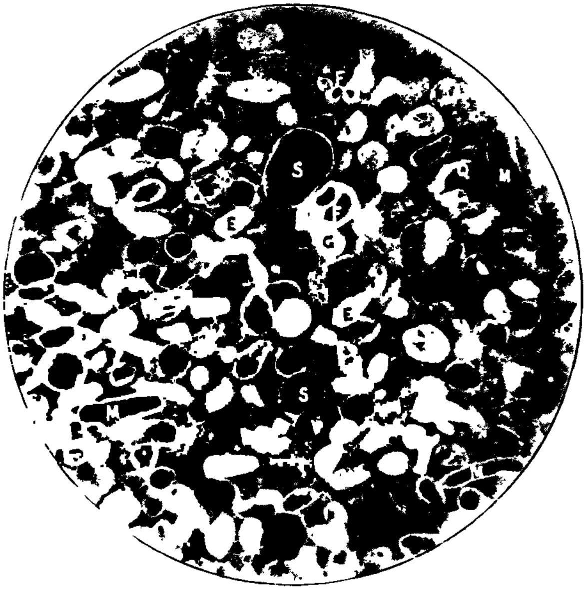
Variations in Composition of Amygdales.

Both amygdales and geodes, necessarily vary very much in composition, but the commonest kinds that are met with in the bedded lavas of Porbandar State and the Province of Káthiáwár generally, consist of aggregated crystals of zeolite (natrolite or mesolite) or of purely siliceous matter such as chalcedony and quartz Less frequently, calcite may predominate ; and sometimes, tolerably

* From the Greek *amygdalos*, an almond, and *eidos*, like.

† From the Greek *gaiodes*, earthy.

PLATE XXXI.



Regd. No. 35.—Fig. 33.—Typical Highest-Grade of Miliolite-Limestone.

Ránawáo Quarries, Ádatiána Heights, Barda Hills.

Magnified 20 Diameters.

From a huge block, which was exhibited to H. E. LORD LAMINGTON, as the highest-grade of 'Porbandar-Stone.' The clastic units are of approximately uniform sizes,—from $\frac{1}{200}$ to $\frac{1}{50}$ inch, and are cemented together by a very fine mosaic of water-clear secondary calcite. **F.**—*Foraminifera* of both littoral and pelagic habit :—*Rotalidæ*, *Globigerinidæ*, but only a few *Miliolidæ*. **M.**—Fragment of shells of *Mollusca*, mostly recalcified but sometimes exhibiting histological structure. **E.**—Bits of calcified areolar tissue and spines of *Echinoidea* **G.**—A green internal cast or pseudomorph of glauconite. **Q.**—Placed below an angular minute fragment of clear quartz, of which there are comparatively few. **S.**—Empty spaces from which particles have dropped out during the processes of preparation.

large geodes of moss-agate may occur. These amygdales and geodes are usually coated with thin crusts of either green or red silicide of iron; and in those instances where the amygdales are of small sizes, ($\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter), approximately spherical shapes and closely crowded in the matrix of the lava, the stone becomes more or less ornamental.

Ornamental Amygdaloids.

Ornamental amygdaloids naturally present a black, blue-black or dark-grey ground-mass when in a perfectly fresh and unaltered condition; but when subjected to sunbaking incipient laterisation or thermal metamorphism, by the contact of subsequent lava-flows or the intrusion of dykes and sheets, their beauty becomes greatly enhanced by the changes in colour of the lava-matrix to purple, brown, maroon and deep red hues. Unfortunately this alteration accompanied by an increase of hardness, does not extend very deeply into the substance of the stone; but there are nevertheless many local instances where considerable quantities of highly ornamental material, are available in sufficiently large blocks and slabs to meet the wants of craftsmen and manufacturers of ornamental goods, such as mantel-pieces, small table-tops, caskets, vases, clock-cases and the like.

Porosity of Amygdaloidal Lava Zones.

Amygdaloidal lavas, by reason of their structure, cannot withstand severe stress or impacts to the same degree as material from the compact or non-amygdaloidal zone of bedded-lavas, and are therefore unsuitable for building or road-making purposes. Water moreover percolates more or less freely through the generality of amygdaloidal lavas, to be arrested and collect underground by the succeeding zone of practically impervious or compact lava.

The Middle or Compact Zone of Bedded-Lavas.

The middle or compact zone of a lava bed, usually attains to much greater thickness than the upper or amygdaloidal region. It may take on the character of a finely textured, sparingly porphyritic basalt of black, blue-black or deep grey colour, except when laid bare by denudation and subjected to monsoon conditions alternating with sunbaking. Under such circumstances the mass of the rock may become changed in both colour and consistency;—sometimes softened and partially or wholly laterised; at other times very sensibly hardened and altered to various hues of grey, brown, purple or red.

From the compact zone, which generally exhibits columnar jointing and spheroidal shrinkages, very large and sound blocks of stone can usually be obtained by blasting, and when these are largely porphyritic, may frequently rank as ornamental stones; while the non-porphyritic varieties, although not so enduring, tough and strong as the hypabyssal granophyres and diabases are yet sufficiently good to command attention for use in building the piers of bridges, as curbstones and copings, for paving-setts and as reliable road-metal.

Economic Products derived from the Middle Zone of Bedded-Lavas.

The third or lowermost zone of the lava-bed is not always present. Its typical development consists of a comparatively thin zone, seldom exceeding six inches in thickness and consisting of a finely textured basalt traversed vertically by branched or simple stem-like amygdales, caused by the molten lava passing over a cold surface, so that jets of steam are ejected upward into the flowing mass, and the latter rapidly solidifying, results in this peculiar style of vesicular structure, which subsequently becomes amygdaloidal by secondary infiltrations.

The Lowermost Zone of Bedded-Lavas with Vertical Stem-like Amygdales.

These bedded-lavas of Cretaceous Age are the representatives of the oldest rocks that are laid bare by denudation in Porbandar State; they are indicated on the coloured chart by a flat green tint, and physiographically are present in the form of wide rock-plains diversified at intervals by isolated but more frequently by ranges of more or less terraced hills of the so-called "hog-backed" type.

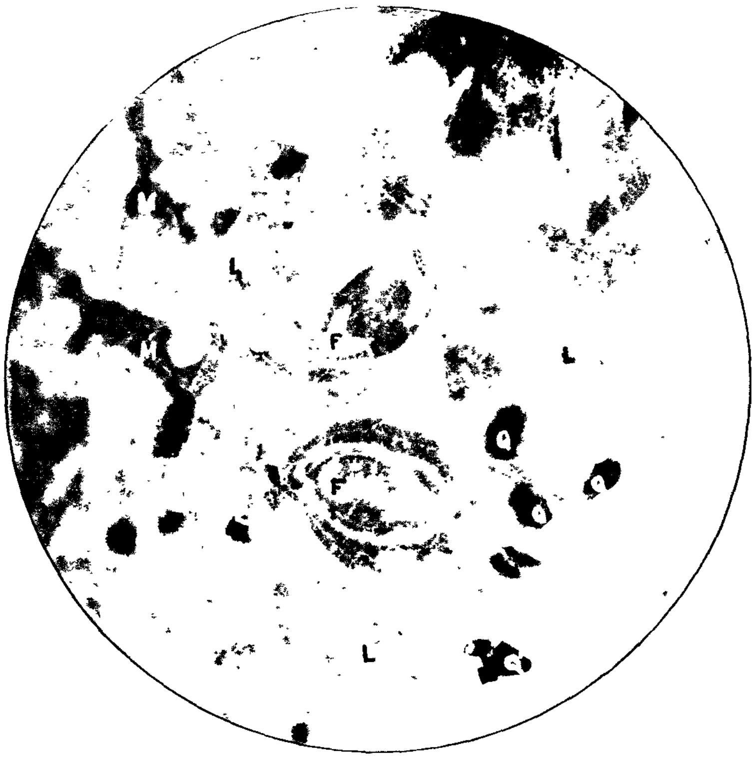
Locale and Physiographical Features of the Bedded-Lavas.

At the dawn of the Eocene Epoch, the concentration of volcanic activity at foci located at the present site of the Barda Group of hills, must have been effectual in shattering the bedded-lavas at that locality and of forming a stupendous mountain of stone. By subsequent denudation the mountain mass must have been shorn to its very base, leaving the present eminences of hypabyssal rocks bare, and buttressed at their boundaries by the older bedded-lavas through which they were thrust.

It is worthy of remark in this place, that in the immediate neighbourhood of the hypabyssal formations at the base of the Barda Hills, the bedded-lavas have become indurated to a marked degree and often show rare and peculiarly metamorphosed minerals and alteration products. These phenomena are strikingly exemplified

Alteration of Bedded-Lava by Contact Metamorphism.

PLATE XXXII



Regd. No. 19.—Fig. 34.—Concretionary Miliolitic Lime Invading Underlying Upper Dwárka Foraminiferal Limestone.

Half-a-mile from Porbandar Creek on Highway-side to Ranawao.

Resolved by WATSON & SONS' ½ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

Matrix of amorphous, concretionary, infiltered lime, **L**, derived by solution from former overlying miliolite. **F.**—Recalcified tests of rotaloid *Foraminifera*, surrounded by narrow zones of clear recrystallised calcite. **M.**—Recalcified relics of shells of *Mollusca*. In other parts of the same section some of these show histological structure. **Q.**—Angular minute fragments of water-clear quartz, one of which, **Q'**, bears endomorphs of zircon. The entire mass is irregularly stained pink-brown with ferric hydrate.

in the rocks registered as Nos. 542 and 543, which were taken from a newly sunk well-shaft 1½ miles NE. by NNE. of the sequestered village of Asiapát at the eastern base of the Barda Hills.

Acid or Light Volcanic Dyke-rocks (Rhyolites).

Cutting through the bedded-lavas on the westward aspect of the Barda Hills, there are many intrusions of dykes, especially in the neighbourhood of Nágka, of light or acid volcanic rocks called rhyolites, some of which are prettily banded; while others have consolidated into black and dark brown intrusions of glassy texture known as obsidians. These dykes are invariably confined to the region at or near by the base of the hills, and are assigned to an early period of the final phase of eruption from the Barda focus or foci. They yield excellent building blocks and smaller ornamental stones, which, however, have not hitherto been utilised in any way, but are nevertheless well worthy of exploitation by reason of their pleasing hues of cool greys, browns, and fawnc olours and the comparative ease with which they can be extracted and tooled.

Basic or Dark Volcanic Dyke-rocks.

In contradistinction to the rhyolites come the dykes of dense black basalt of excessively fine texture and frequently of gigantic dimensions, which traverse the countryside from their foci of eruption in the Barda group of hills often for many miles above and underground; the former being indicated on the coloured chart by thin red lines. Like the rhyolites these must have been intruded during the final phases of eruption in Eocene times immediately succeeding the extrusion of the acid volcanics. They yield an abundance of intensely hard shingle suitable for road-metal, second only in enduring properties to the best of granophyres.

Locale of the Gaj, (Miocene). Group of Beds.

Prolonged denudation must have followed the cessation of volcanic activity, and there are evidences to show that a subsequent submergence of the southern and south-western borderland of the Province must have taken place in Tertiary times, for deposits of Gáj (Miocene) strata abounding in characteristic fossil remains, are to be found directly overlying the igneous rocks of the Deccan-Trap Period, right up from the coast line to the base of the Barda group of hills in Porbandar State.

The Gaj and Dwarka Groups of Beds.

There does not appear to be a very wide break in succession between these Gáj rocks, which are mostly of the nature of yellow, limonitic fossiliferous limestones and marls, and the succeeding or overlying Dwárka Group of beds; but it is clear that a period of elevation and then of subsidence must have supervened, presumably during the latter days of the Tertiary Age, to account for the differences in lithological character and fossil contents of the two groups of Gáj and Dwárka beds; while the latter evidently went on accumulating uninterruptedly right into the Pleistocene Period.

Economic Products from the Gaj Beds. Pindaralite and Bharwaralite.

The Gáj Group of beds yield a few excellent ornamental stones, the most noteworthy of which occurring in merchantable quantities have been named by the writer after their principal localities, Pindáralite (in Navánagar), and Bhárwárálite from the vicinity of Bhárwárá in Porbandar State. The first of these has been sparingly employed for local buildings and as an ornamental stone in the Palace of H. H. THE MÁHÁRÀJA JAM SAHEB OF NAVANAGAR; while the second, an apparently homogenous stone of a rich cinnamon hue, has not yet been utilised in any way.

Economic Products from the Dwarka Group of Beds.

Of the Dwárka Group of beds, which in Porbandar State attain to quite an insignificant total thickness of strata, many important areas of building materials are available on account of the widespread occurrence of the beds thickly along the whole of the coastal borderland and thinning down to nil right up to the base of the Barda Group hills at Adátiána, Ránáwáo and even far beyond.

The Base of the Dwarka Group of Beds, Kunchri and Degam-stones.

The base of the series, resting conformably on the Gáj limonitic limestone, and well exposed in the neighbourhood of Degám is constituted by a coarse conglomerate largely composed of the valves of lamellibranchiate shells. This may or may not be overlaid by a compactly textured white to pink foraminiferal limestone capped by thinly laminated alternately coarse and fine layers. The former may be seen in typical development on the bed of Visáwára Creek-mouth and in well-shafts at Sirinagar; while the latter furnishes the bulk of the enormous output of what are commercially known as Kunchri and-Degám stones respectively, so largely used for the foundations of buildings in Porbandar City.

PLATE XXXIII.

Regd. No. 98.—Fig. 35.—Incipient Spherulitic Felsite.

Summit of Bhatwari Dhar, Barda Hills.

Resolved by WATSON & SONS' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

Cryptocrystalline felsitic ground-mass, **G**, in subordinate development. **S.**—Sub-longitudinal and oblique sections of sanidine. The elongated sections shows multiple twinning between crossed nicols. **A.**—Sub-idiomorphic green crystals of augite. **A'.**—Incipient green spicular crystals of augite **A''**—Indigo-coloured, moniliform, radiating trichites of pyroxene. **M.** Opaque black magnetite. **E.**—Honey-yellow abnormal epidote.

Attributes and uses of Kunchri and Degam-stones.

The Kunchri-stone is much discoloured, and more fissile than the Degám-stone, but it is harder by reason of its mode of occurrence, being quite superficial and only 2 or 3 feet in thickness, so that the bulk of the material gets hardened by sunbaking. Degám-stone, on the other hand, while belonging to the same horizon, is developed more deeply from the surface, down to as much and sometimes more than 10 feet. It is of a white colour tinged with laminæ of pink, and not so fissile as its Kunchri counterpart. Both varieties are available in slabs and blocks of large sizes, and when laid with the lamination in a horizontal position are accounted to be very strong and capable of withstanding enormous stress and crushing force, so that they are in universal local demand for foundations, but being of coarse texture and inferior quality cannot realise prices to cover the charges for freight to foreign ports.

Kunchri and Degam-stones under the Microscope.

Under the microscope both Kunchri and Degám stones cannot be readily distinguished from the later-formed miliolite-limestones, and all of them probably belong to the Plesitocene Period of the geological record.

Consolidated Shell-sand of the Dwarka Group of Beds.

Overlying the Kunchri and Degám stones in other localities and probably contemporary with them comes an inconsiderable thickness of very variable beds of a hard and tough limestone which the writer has named "Consolidated Shell-sand." This material occurs in finest development along the coastal borderland of Porbandar State and gradually tails down to nil inland as far as the base of the Barda Group of hills ; being detectable far beyond the town of Ránáwáo on the surface of the highway-side approaching and beyond Virpur.

Consolidated Shell-sand is clearly the relic of a former beach probably belonging to the Dwárka Group of beds. It occurs mostly in the form of slabs from 2 to 6 inches in thickness ; but along the shore at low-water mark and notably at the village of Tunkra and beyond, to as far as the town of Navibandar can be extracted in blocks of large dimensions ranging from 6 inches to a little more than 2 feet in thickness.

Sufficient material is available to make the Consolidated Shell-sand, a lasting commercial-asset but it is prone to vary very greatly in texture and physical properties, even in the same quarry site, from a very coarse mass in which large shells and big pebbles can be clearly discerned without artificial aid, to a very compact rock composed of finely comminuted shells, entire tests of polythalamous foraminifers, minute quartz grains and equally small and well-rounded fragments of previously formed Gáj limonitic limestone, all firmly bound together by a matrix of secondary or re-crystallised calcite, usually in the form of water-clear mosaics.

Structure of the Consolidated Shell-sand.

At Tunkra, the matrix of calcite is differentiated into radiating fibres, which endows thin sections when viewed under the microscope with quite a unique and exceedingly beautiful appearance.

Unique Variety of Consolidated Shell-sand at Tunkra.

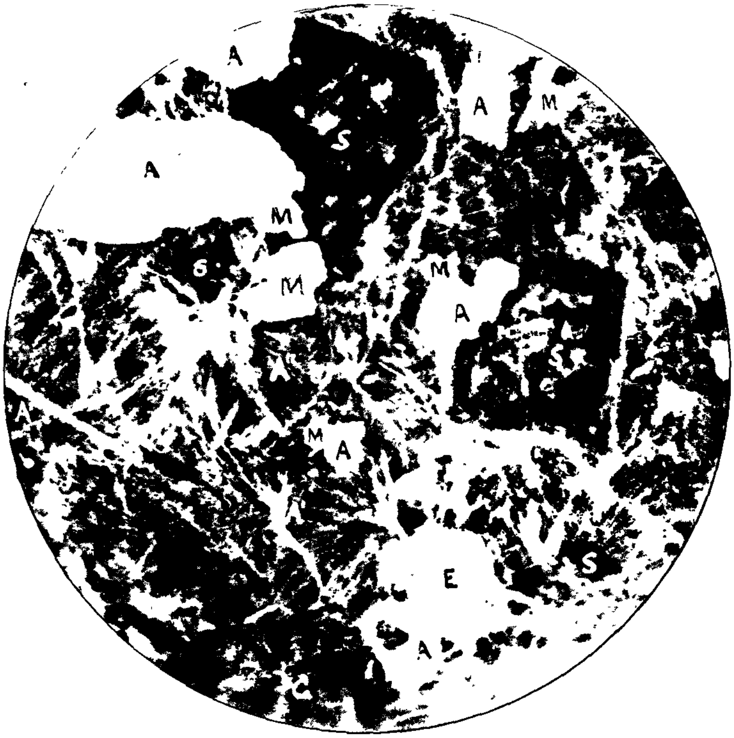
These raised-beaches of consolidated shell-sand frequently yield large slabs and even goodly-sized blocks of very compact greyish-white stone of such fine texture that they admit of being polished and when struck by a hammer on a thin edge, ring with the clang of a metallic bell. Such specimens could, of course, be profitably utilised for the manufacture of a large variety of useful and ornamental wares, such as table-tops, clock-cases and the like ; but the material whether coarse or fine is deserving of more extended use for the erection of dwelling-houses, especially at the sea-side by reason of being practically unaffected by salt spray, probably on account of its origin along the littoral of the sea.

Physical Properties and uses of Consolidated Shell-sand.

In patches along the coastal borderland, and indiscriminately covering all the older formed rocks which were exposed by denudation during the period of its deposition in later Pleistocene days, come the undenuded remains of the best known of merchantable stone known as 'Porbandar-stone' or Miliolite-limestone, which fills up every place of vantage throughout the length and breadth of the Province, and leaves its line of limitation on the hill-sides, to prove that the whole of the country was submerged with the exception of its loftiest hill-tops. The mean limestone limit in Porbandar may be given roughly at 300 feet above the sea-level.

Distribution of 'Porbandar stone' or Miliolite-limestone.

PLATE XXXIV.



Regd. No. 98.—Fig. 36.—Incipient Spherulitic Felsite.

Summit of Bhatwari Dhar, Barda Hills.

Resolved by WATSON & SONS' ½ *inch Objective,* 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

No well-developed ground-mass is shown in this field of view. **S.**—Transverse sections of colourless sanidine, full of inclusions. **A.**—Idiomorphic crystals of green augite. **A .**—Incipient spicular crystals of green augite of a second generation. **A ′.**—Moniliform radiating, indigo-coloured trichites of pyroxene, inaugurating the formation of spherulites. **M.**—Opaque black magnetite. **E.**—Monoclinic honey-yellow abnormal epidote. **G.**—Cryptocrystalline felsite or ground-mass.

The succession of rocks in the region of the Barda Group of hills may be best elucidated by referring to the diagram on Plate XXX.

The Succession of Rocks in the Region of the Barda Group of Hills

It will there be seen at a glance that the mountain-massive of felsites and granophyres thrust through the previously formed bedded-lavas of the Deccan-trap Period and buttressed at its base by the latter, is eroded to form deep gorges and a more or less definite and continuous cradle at the foot of the formation. The plain below, which stretches westward to the sea-coast, is covered by irregular patches of Gaj limonitic-limestones and conglomerates overlaid by an appreciable deposit of Dwárka-beds shell-sand, and capped every here and there by varying thicknesses of miliolite-limestone — The latter attaining to its maximal development, sporadically, along the basal cradle of the hills and their numerous gorges. The limestone line of limitation in this region ceases abruptly at an average of about 300 feet above the level of the sea.

PETROGRAPHICAL DETERMINATIONS.

Leading Phyla of the Economic Building and Ornamental Stones of Porbandar State.

PHYLUM A.—MILIOLITE-LIMESTONE.

MORE THAN HALF-A-CENTURY has elapsed since this valuable building stone was first exploited on a commercial scale and exported from Porbandar to the markets of Peninsular India. It has consequently acquired the appropriate trade designation of 'Porbandar-Stone' irrespective of the localities from which supplies have been drawn.

Leading Types of Building-stones: Miliolite-limestone or 'Porbandar Stone.'

By virtue of its intrinsic merits, and being still available, at its best, from the original extensive quarry-sites on the Ádatiána Heights near Ránáwáo, the material continues to command, and is therefore now accorded a premier place in these pages.

The many localities where merchantable miliolite has been found available, its geological age, mode of occurrence, physical properties, chemical composition, numerous varieties, commercial grades and qualities, microscopic structure, specific uses, and the alterations which it undergoes, have one and all been sufficiently treated of in the foregoing pages and may be severally referred to by consulting the 'Table of Contents' and Index to this volume.

PLATE XXXV

Regd. No. 538.—Fig. 37.—Spherulitic Felsite.

Krishna Jhar, 1 mile NNE. of Summit of Babia Dungar, Barda Hills.

Resolved by WATSON & SONS' $1\frac{1}{2}$ *inch Objective*, 0·17 *Numerical Aperture*.

Amplified 15 Diameters.

In this sunbaked, ornamental stone, the ground-mass is of a dual character :—**G.**—Comparatively coarse, and, **G′**, almost ultramicroscopic in texture. **S.**—Large, idiomorphic, twinned crystal of sanidine, showing rectangular reticulations, and forming the nucleus of a large spherulite. **Sp.**—Radiating fibrils of the spherulites. A trifle of decayed small crystals of magnetite and incipient spicules of green pyroxene may be detected with higher powers in the more finely textured areas of the ground-mass. **E.**—Empty spaces.

In order, however, to convey a correct and more vivid impression of the intimate structure of the stone, the sizes, condition and correlation of its clastic units, the aspect and true nature of its binding matrix (upon each and all of which collectively the economic value of samples depends), it will be necessary to supplement an accurate pictorial illustration ; and this therefore is here afforded by Fig. 33, Plate XXXI, accompanied by its explanatory text.

Variations in Texture and Composition of Miliolites.

It has already been recorded, that the miliolite deposits invariably differ in texture and the sizes and nature of their clastic units, both vertically and horizontally,* and it has been found that the vertical variations are always the most pronounced. Thus, in the large open quarries on the Ádatiána Heights, the coarsely textured superficial beds pass insensibly downward to a more or less finely textured stone of the best grade ; and it is according to the thickness of these superior beds that the quarry site is esteemed by the quarry contractors. At an average depth of about 30 feet from the surface, the rock grows hard and increasingly gritty from the presence of particles of the mountain-massive (felsites and granophyres), upon which the limestone was deposited.

Sedimentation of the Miliolites during the Pleistocene Period.

Evidences in the field go to show, that the sedimentation of the miliolites must have taken place during the Pleistocene Period long after the final strata of the Dwárka Group of beds had been formed, elevated and denuded ; and overwhelming proofs exist to point to the circumstance, that, previous to the general subsidence of the best part of the Province, atmospheric agencies had been active in the unequal wearing-down of the then existing rocks to expose a very varied surface, *viz.*, bedded-lavas and dyke-rocks, laterites, felsites and granophyres, Gáj conglomerates and limestones, and Dwárka limestones, conglomerates, and flagstones of consolidated shell-sand.

Littoral as well as Deep-sea Origin of the Miliolites.

Upon each and every one of these, the miliolite must have been impartially deposited, mainly as a littoral-marine, but also as a tolerably deep-sea accumulation. In the former instance, coarse and fine conglomerates constitute the basement beds of the miliolites, containing rounded and sometimes angular fragments of the underlying and subjacent rocks, and organic

* *Ut supra*, p. 18.

remains of littoral animals and plants,—*Foraminifera*, *Bryozoa*, echinoderm tests and spines, shells of molluscs, nullipores, etc. In the latter, there is little if any conglomerate of any kind in the lowermost beds of the miliolite, which rests directly upon the underlying rock, and is composed principally of finely comminuted shells of molluscs, angular specks of quartz and other minerals, and many tests of both pelagic and deep sea *Foraminifera* such as of the genera *Globigerina*, *Textularia*, *Pulvinulina*, and, occasionally only, of *Miliolina*, while the nullipore, *Lithothamnion* and *Bryozoa* remains are rarely present. All of these, as usual, are bound firmly together by a fine mosaic of secondary water-clear calcite.

Miliolite Basement-beds.

Miliolite basement-beds accordingly proclaim the kind of rocks upon which they were deposited as well as of rocks which happened to exist in the immediate neighbourhood; and this frequently gives birth to many varieties of the stone, which are prone to be puzzling unless examined in relation to their surroundings in the field or placed as thin sections under the microscope in the laboratory. Of such a nature is the miliolite of a deep, purple-red colour, which, registered as No. 248, was, with a coarse, shelly conglomerate,—No. 247,—found overlying a cap of laterite, 2 miles SSW. of Wadála. In these instances, both the conglomerate and miliolite have simply been heavily indued with ferric hydrate stain from the adjoining and subjacent laterite.

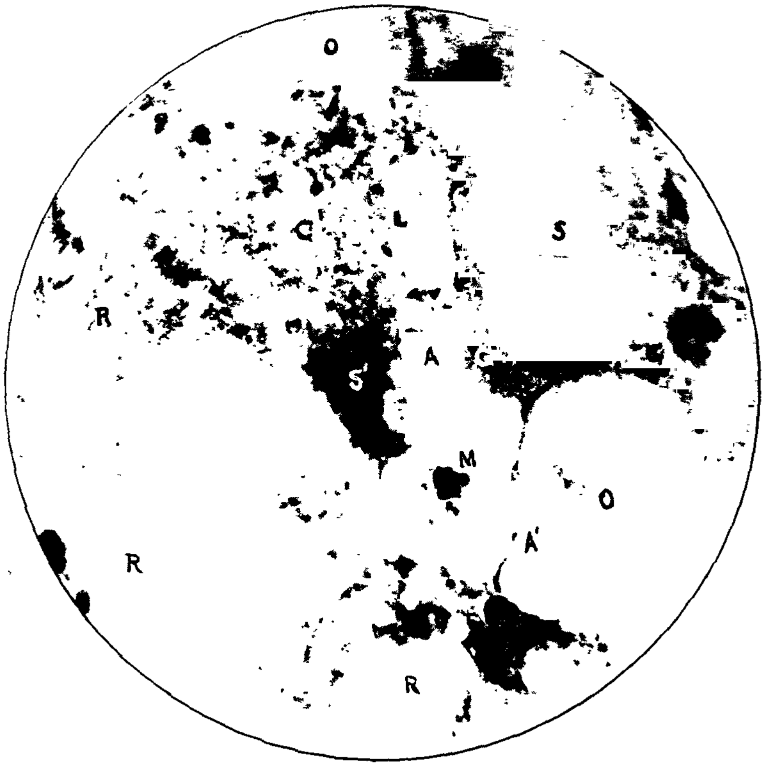
Concretionary Character of Milliolite Basement-beds.

Again, the basement-beds of miliolite, whether conglomeratic or not, frequently assume a concretionary character, due to the solution of its limy constituents by carbonated meteoric waters, and the re-deposition of the lime at lower levels. Frequently, the underlying beds, that are subjected to such infiltrations, consist of Dwárka Group foraminiferal limestones in which only vestiges of the organic units can be detected in a thoroughly recalcified condition embedded in a matrix of ultra-microscopic, particles of lime, usually stained with ferric hydrate and also enclosing numerous angular grains of water-clear quartz.

Examples of Concretionary Miliolite Basement-beds.

Good examples of rocks thus partially derived from overlying miliolites, by solution and re-deposition of amorphous lime, in concretionary form are present at the surface in very many parts of the State, notably by the side of the Railway-cutting, about 1 mile ENE. of Ránáwáo

Plate XXXVI.



Regd. No. 34.—Fig. 38.—Spherulitic Felsite.

Alongside Railway-siding, near "Navri" Miliolite Quarry No. 62.

Adatiana Heights, Barda Hills.

Resolved by Watson & Sons' 1 *inch Objective*, 0·21 *Numerical Aperture*.

Amplified 30 Diameters.

This picture portrays a more advanced phase in the differentiation of felsites than either Fig. 5, Plate IV or Fig. 37, Plate XXXV. **G.**—Ground-mass of cryptocrystalline felsite. **S.**—Sub-idiomorphic section of twinned crystal of sanidine. **S'.**—Fragment of clear colourless sanidine. **O.**—Brown, (altered), orthoclase showing rectangular reticulations. **R.**—Radiating fibrils of spherulites;—orthoclase, quartz and pyroxene. **A.**—Elongated idiomorphic crystal of green augite, intergrown with laths of sanidine in ophitic fashion. **A'.**—Incipient spicular green augite. **M.**—Magnetite.

Station, and about $\frac{1}{2}$ mile from the bridged Creek at Porbandar City on the highway to Ránáwáo, where, by reason of its hardness, toughness and compact texture, the material has been largely extracted for road-metal. The intimate structure of this stone, which is thus possessed of scientific interest, is well shown by the photomicrographic picture, Fig. 34, Plate XXXII.

Peculiar Miliolite of Chirora-ka-Tobra.

REGD. NO. 415.—The small hillock called Chirora-ka-Tobra, which, during the monsoons, forms an islet rising to the height of 56 feet above the sea level, furnishes a much-decayed variety of limestone closely resembling the miliolites.

Under the microscope, the clastic units appear to be of tolerably uniform sizes, ranging from $\frac{1}{200}$ to $\frac{1}{100}$ inch across. They comprise:—(I).—Numerous well-rounded particles, heavily stained with yellowish-brown-red ferric hydrate, but so altered as to have lost all traces of organic or other structure. (II).—Recognisable tests of *Foraminifera*, chiefly rotaliform, and also belonging to the family *Textularidæ*. (III).—Slightly elongated chips of the shells of molluscs. (IV).—Bits of the calcified areolar tissues and spines of echinoids. (V).—Subordinate angular grains of colourless quartz of minute dimensions,—$\frac{1}{400}$ to $\frac{1}{200}$ inch across. The cementing matrix consists of an excessively fine mosaic of colourless calcite, the granules of which rarely exceed $\frac{1}{1000}$ inch in diameter.

PHYLUM B.—HYPABYSSAL ROCKS.

Hypabyssal Rocks of Porbandar State.

NEXT IN COMMERCIAL IMPORTANCE to the miliolite-limestones of Porbandar State, come its hypabyssal rocks of probably Eocene Age, which have since been exposed by denudation to form the Barda Group of hills and its numerous spurs and outliers.

Up to the present time, no serious effort has been made to exploit or utilise the rich variety of these incomparably valuable building and ornamental stones, in spite of the fact that progressive engineers, architects and builders and contractors throughout India, have, for many years, been clamouring in vain for high-grade road-metals, paving-setts curbs and copings, and building-blocks capable of resisting severe crushing force to meet the requirements of docks, harbours and embankments.

Porbandar port is peculiarly well situated for supplying, at a minimum of cost, all the stone markets of India with just the materials wanted by reason of its proximity to numerous practically inexhaustible quarryable sites for felsites and granophyres in almost every stage of development, and calculated to meet the most exacting wants. The granophyres, as a rule, constitute the bulk of the central portion of the mountain-massive ; while the felsites are usually to be found forming its many spurs and outliers.

Felsites and Granophyres.

Ample information has already been recorded in the pages of these reports concerning the mode of occurrence, general properties and uses of these stones, average samples of which have been chemically analysed, specially for this report, by MR. R. E. J. M'CULLY of THE INDIAN CEMENT CO., LIMITED, as follows :—

Quantitative Chemical Analyses of the Hypabyssal Rocks of the Barda Hills.

ANALYTICAL TABLE OF BARDA HILLS ROCKS.

Registered No	33	98.	30.
Moisture	Trace	*Nil.*	2.15
CO_2	1.90	.74	5.54
SiO_2	68.70	70.50	67.90
Fe_2O_3	5.82	15.34	5.60
FeO	1.10	Trace.	*Nil*
Al_2O_3	14.08	3.30	13.72
CaO	6.60	6.40	1.94
MgO	1.42	2.83	2.82
Alkalies	.38	.89	.33
	100.00	100.00	100.00
Specific Gravity	2.587	2.700	....

This table of chemical analyses, is in strict accordance with the determination of the constituent minerals revealed by examination of thin sections under the microscope, with ordinary transmitted and polarised light ; so that the optical analyses of the samples, and their correct designations may now be recorded for the first time as hereunder :—

Felsites and granophyres are the names which will here be employed

PLATE XXXVII.

Regd. No. 34.—Fig. 39.—Spherulitic Felsite.

Same site as that of Fig. 38. Adatiana Heights, Barda Hills.

Resolved by WATSON & SONS' $\frac{1}{2}$ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

To display the intimate structure of the centre of a well-developed spherulite. **S.**—Idiomorphic hexagonal section of a carlsbad twin of colourless sanidine, which gives straight extinction, exhibits an upper zoned border, **Z**, of secondary refringent products, and traces of multiple twinning between crossed nicols. This crystal forms the nucleus of a spherulite. **A''.**—Radiating fibrils, here principally of the nature of indigo-coloured trichites of pyroxene mingled with fibrils of felspar and quartz to constitute the substance of the spherulite. **E.**—Honey-yellow crystal of abnormal epidote after augite.

to indicate the extremes of the type now under consideration. The former consist essentially of an obscure or cryptocrystalline intergrowth of felspar and quartz, and appear to be homogeneous throughout when viewed by natural transmitted light under the microscope; but, when polarised light is brought to bear upon the thin sections, the two minerals can be readily distinguished in form of allotriomorphic, irregular, minute areas, separable by the slight differences exhibited by their interference tints when the nicols are crossed and the section rotated.

Optical Analyses of Felsites and Granophyres.

Accessory minerals such as incipient microscopic grains and laths of greenish pyroxene and more or less well developed microlites and crystals of magnetic iron-ore are usually present, and serve to endow the stone, with its characteristic colour. Thus, when the rock contains a superabundance of magnetite in a perfectly fresh condition, it assumes a dark, and sometimes almost jet-black colour; while the paucity of the iron-ore may be gauged by its many shades, ranging from white to greys. Again, when the iron-ore and less frequently, the accessory pyroxene undergo alterations by epigene reactions, such as oxidation and alternate sun-baking and monsoon conditions, the originally black, whitish or grey felsite assumes various hues of yellowish-brown, brown, fawn, red and purple; and, without deterioration in hardness and other physical properties, the stone becomes distinctly ornamental.

Colour of Hypabyssal Rocks mainly due to their Accessory Constituents.

Chemically, the felsites do not differ from the granophyres, but they are distinctly vitreous and splintery, breaking with a conchoidal fracture; and although intensely hard, cannot withstand severe crushing force, so that they are not suitable for use as dock-building blocks or for road-metal. On the other hand, their superior hardness, conjoined with a capacity for taking on a high polish and of withstanding attrition, renders them invaluable for tiles, floorings, steps and landings; while some of them are differentiated into spherulitic and porphyritic varieties, and especially when altered by sunbaking and monsoon conditions, acquire an ornamental character.

Economic Attributes of Felsites.

Good examples of ordinary felsites, exhibiting the structure of the ground ground-mass shown on Fig. 5, Plate IV., are not of very frequent occurrence in the State of Porbandar, although they are largely

represented among the hypabyssal rocks of the adjoining Alech Hills in Navánagar State, and by sundry outlying eminences to the SW. of the Baroda Group of Hills, such as at Dhebar Dhár.

The next phase in the development of felsites, is typically exemplified by a rock which forms the mile-long nether eminence called Bhatwári Dhár, flanking the base of Bhatwári Dungar in the Barda Group of hills, and approximately running parallel with the Railway line eastward from Ránáwáo Station. The rock is intensely black when quite fresh and closely resembles a compact basalt or dolerite, for which it was excusably mistaken, especially as true basalt dolerite dykes of huge dimensions were found by the writer to occupy similar relative positions with reference to the mountain-massive, at Pachhtar and near Mokhána in Navánagar State.*

The Bhatwari Dhar Stone

Registered as No. 98 in the State Geological Collection, the Bhatwári Dhár stone is, as already noted, intensely black when quite fresh. Huge boulders crowning the summit and covering the slopes of the hill, although exposed to the vicissitudes of the weather for prolonged periods, yet preserve their original freshness by the formation of a bright brick-red hæmatitic pellicle. These boulders when broken by sledge-hammers, are prone to fracture rectangularly at unexpected places ; so that it is extremely difficult to trim building-blocks of any given dimensions. The stone, however, breaks readily into an angular shingle ; and the fragments, which can then be screened to secure uniformity in gauge, are so tough and strong and capable of withstanding such severe attrition and crushing strain as to be much esteemed for a high-grade road-metal. It is now being tested by the Chief Engineer, MR. MEASHAM LEA, M. INST. C.E., of Karachi Municipality.

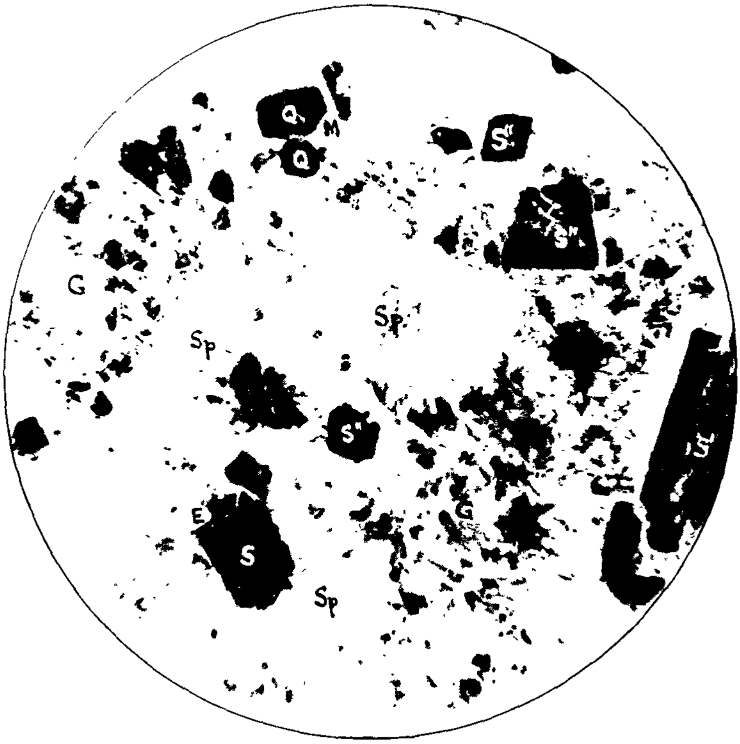
Chemical Composition of the Bhatwari Dhar Stone.

Chemically the Bhatwári Dhár stone approximates to the composition of a typical granophyre, as shown by the analytical table given above.† Its specific gravity is appreciably higher than that of an average granophyre, while it contains less carbonate of lime, less alumina and ferrous oxide, more magnesia and potash, and a marked preponderance of ferric oxide and of silica.

* 'Economic Geology of Navánagar State', by E. HOWARD ADYE, Bombay, 1914, p. 46.

† *Quod vide*, p. 94, *Registered No.* 98.

Plate XXXVIII.



Regd. No. 34.—Fig. 40.—Spherulitic Felsite.

Same site as that of Fig. 39. Adatiana Heights, Barda Hills.

Resolved by Watson & Sons' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

To show the general structure of a large field-of-view. **Sp.**—Entire spherulites with their nuclei of sanidine. **S.**—Twinned crystal of sanidine, which is shown more highly magnified by Fig. 39, Plate XXXVII. **S**.—Longitudinal section of sanidine showing inclusions of the felsitic ground mass. **S**.—Transverse and oblique sections of sanidine. **G.**—Cryptocrystalline or felsitic ground-mass, containing pyroxene spicules and magnetite microlites too small to be distinctly shown by this power. **M.**—Crystal of opaque black magnetite. **Q.**—Idiomorphic crystals of quartz. **E.**—Abnormal epidotised augite of honey-yellow colour.

Microscopic Determination of the Bhatwari Dhar Stone:—'Incipient Spherulitic Felsite.'

Microscopical determinations enable one to give the stone its correct name as an 'Incipient Spherulitic Felsite'. When thin sections are examined under low powers ($1\frac{1}{2}$ inch and 1 inch objectives), the cryptocrystalline ground-mass of the sample may be seen to occupy quite a subordinate space; while the closely crowded spherulites, mostly formed around nuclei of colourless sanidine crystals constitute the bulk of the rock mass. Some of these sanidine crystals, when examined in polarised light show traces of multiple lamellation, which points to the probability of a variety created by internal intergrowths of monoclinic and triclinic felspars. The elongated crystal S, Fig. 35, Plate XXXIII ,is of this character.

Distinction between 'Felsitic' and 'Granophyric' structure.

It may be noted that the cryptocrystalline, felsitic ground-mass, with its usual accessories of incipient crystals and microlites of magnetite and greenish pyroxene, serves to draw a sharp line of demarcation between the felsites and the granophyres; for the ground-mass of the latter group is essentially micropegmatitic, or composed of a microscopic intergrowth of felspar and quartz, known as the *granophyric* structure.

Accessory Constituents of the Bhatwari Dhar Stone.

Pyroxenic constituents in No. 98, are manifested morphologically in three distinct forms :—(α)—As radiating fibrils entering into the composition of the spherulitic structure surrounding nuclei of sanidine, the former of which likewise include brownish radiating fibrils of probably orthoclase felspar and of a little clear quartz. The pyroxene fibrils under higher magnifying powers ($\frac{1}{2}$ to $\frac{1}{4}$ inch objectives) can be resolved into indigo coloured moniliform structures resembling *margarites*, or 'embryonic crystals' called *crystallites*, in the semblance of a string of pearls.* (β)—As elongated, distinctly greenish, skeleton laths or spicules composed sómetimes of several units conjoined and generally associated with probably separated crystals of black magnetic iron-ore. (γ)—As tabular, often regular six-sided, idiomorphic crystals of green augite, almost always bearing endomorphs of magnetite. Magnetite moreover in minute black and opaque octahedra, crystal aggregates and spicules, is indiscriminately distributed throughout

* F. RUTLEY, 'Mineralogical Magazine', Vol IX, 1891, pp. 261-271. COHEN 'Sammlung von Mikrophotographien......von Mineralien und Gesteinen', 3, Stuttgart, 1899, Pl. VI.

the field of view. Lastly there come, in some sections many tabular, frequently six-sided, very highly refractive, honey-yellow monoclinic crystals, of unascertained composition, which may possibly be abnormal forms of epidote derived by metasomatism from augite.

Cleaved structure in Hypabyssal Rocks.

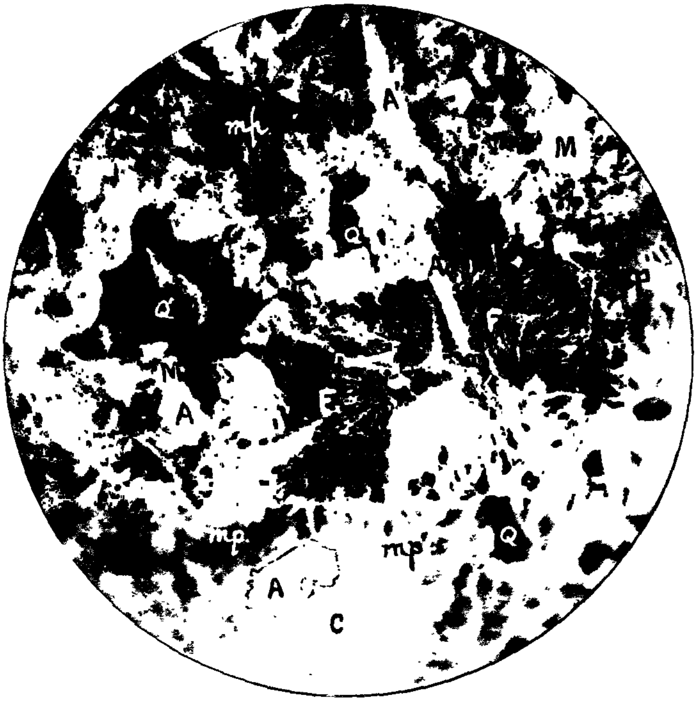
There are many instances where felsitic and granophyric dykes, sometimes of considerable dimensions have been thrust through fissures or lines of weakness in the previously consolidated mountain-massive; and these, by reason of the enormous lateral pressure brought to bear upon the moving molten magma, eventually solidify into more or less cleaved masses;—the cleavages running at right angles to the direction of flow. Both felsites and granophyres exhibit cleaved structure in the Barda Group of hills, and it may be presumed, that being identical in chemical composition, these two varieties result,—the former, by rapid and the latter by more tardy congelation, whereby distinct crystallisation can be seen to have commenced by intergrowth and other manifestations of the constituent mineral units.

Examples of Cleaved Felsites

Typical of such rocks, a remarkably good example of a "Cleaved Felsite", registered as No. 548, in the State Geological Collection, was found exposed, and somewhat altered by meteoric agents, from an original grey to a rusty-brown colour, about 500 yards NNW., of Sajanawála Nes, near the eastern limits of the Barda Group of hills.

Examined under the microscope, thin sections of this specimen revealed an apparently homogeneous ground-mass of ultramicroscopic texture, flecked every here and there by patches of water-clear quartz, and curiously criss-crossed by numerous parallel lines of incipient crystals of probably originally green pyroxene associated with diminutive separations of magnetite. When the two principal sets of parallel lines intersect, as they occasionally do, they give an average angle of 87°6′, which corresponds exactly with the cleavage angles of augite. Between crossed nicols, the apparently homogeneous ground-mass is shown to be cryptocrystalline, and several faint outlines can be identified as those of elongated crystals of sanidine in an incipient condition; while the blebs of quartz are revealed in mosaics of differently orientated, allotriomorphic units. Both pyroxene and magnetite have undergone

Plate XXXIX.



Regd. No. 55.—Fig. 41.—Felsitic Granophyre.

Outlying outcrop of Spur, 3 miles ENE. of Ranawao Station.

Resolved by WATSON & SONS' 1 *inch Objective*, 0·21 *Numerical Aperture*.

Amplified 30 Diameters.

The ground-mass here is shown to consist almost entirely of micropegmatite, **mp** but there are also a few small patches of cryptocrystalline felsite, **F** invaded by subradiating indigo-coloured, moniliform rods and trichites. A few idiomorphic crystals of clear sanidine obtain in other parts of the preparation. **C.**—Spherulite composed of centric system of micro-pegmatitic radiating fibres. **Q.**—Quartz in optical continuity with quartz of micropegmatite. **Q.**—Mosaics of interstitial quartz. **A.**—Idiomorphic green augite. **A.**—Spicular green augite. **M.**—Magnetite.

alteration to a dark brown colour by oxidation ; but the entire mass remains very hard and compact on account of having been subjected to prolonged sun-baking.

About 50 yards farther, or 550 yards NNW. of Sajanawála Nes, a precisely similar rock, but only partially cleaved, forms a small outlying knoll which can be traced to a spur from the eminence called Ránásár Dhár, near the State boundary. In this specimen the parallel, criss-crossed lines of incipient crystals can be distinctly resolved, under powers of over 50 diameters, into particles of green pyroxene and separations of black opaque magnetite.

Spherulitic Felsites

More highly differentiated come the varieties known as ' Spherulitic Felsites', which, especially when altered by alternate sun-baking and monsoon conditions, yield many very beautiful ornamental stones, capable of taking a brilliant polish ; and, being available in sound blocks of tolerably large sizes, can be turned to profitable account in many special arts and crafts. Such are the specimens, found exposed in almost unlimited development at Krishna Jhár, 1 mile NNE. of the summit of Bábia Dungar in the Bardar Group of Hills, and also in form of a very broad dyke which runs from NNW. by W. to ESE. by E. at the base of Piara Dungar, called Javantára Gárá, which is crossed by the Railway line. The Krishna Jhár rock is at present inaccessible ; but the Javantára Bárá site, where the stone has undergone slightly more alteration, lies by the roadside to Bordi, and can therefore be readily extracted and conveyed to Porbandar Docks, especially if a loading platform could be established at Bordi—as strongly recommended in the narrative portion of these reports.*

Ornamental Spherulitic Felsites of Krishna Jhar, and Javantara Gara.

Spherulitic Felsite from the Krishna Jhár site has here been chosen as typical of this variety, on account of its superior freshness. Its groundmass of felsite, is comparatively coarsely textured at some places, while at others it is ultramicroscopical and only resolvable as a cryptocrystalline structure, when viewed between crossed nicols. The field is studded with phenocrysts of the clear and colourless variety of orthoclase felspar known as sanidine, which serve as nuclei for radiating fibrils of felspar and quartz, (the former predominating), to together constitute the closely

Microscopical Determination of the Spherulitic Felsite of Krishna Jhar.

* *Quod vide*, page clxxx

aggregated bodies, called *spherulites*. Sometimes the otherwise clear sanidine crystals show meshworks in grey of the rectangular reticulations so characteristic of ordinary orthoclase felspar; at other times the sanidine exhibits polysynthetic twinning, and thus points to an intergrowth with a triclinic felspar. A few decayed small crystals after magnetite may be detected, while the pyroxene is represented by oxidised spicules especially in the ultra-microscopic areas of the ground-mass.*

Ornamental Spherulitic Felsites from the Adatiana Heights, Ranawao Railway-line and Ladha Dhar.

Another noteworthy variety of Spherulitic Felsite, (registered as No. 34), which can scarcely fail to command a good demand so soon as it becomes known, occurs exposed in abundance, alongside of the Railway-siding, and for fully fifty yards ENE. thereof, close by the 'Navri' Miliolite-quarry, No. 62, on the Ádatiána Heights near Ránáwáo Station. Other good sites for similar material have been registered respectively as No. 96, exposed by the Railway-cutting nearly ½ mile ENE. of Ránáwáo Station, and No. 528, which extends from the Khámbala roadside up to the summit of a hill called Ladha Dhár, which is situated approximately 1⅝ miles SE. by ESE. of the hill-side village of Khámbala.

It will be sufficient in this place to take No. 34, as typical of this variety of felsite as follows :—

Megascopic Characters of the Spherulitic Felsite from the Adatiana Heights.

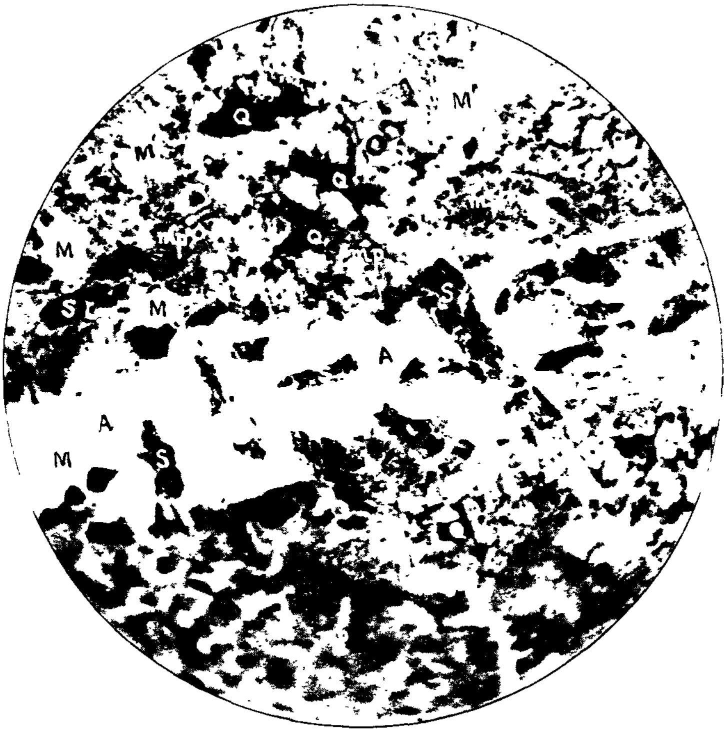
Megascopically the rock exhibits a comparatively light-grey ground-mass, closely studded with dark-grey sub-circular spots ; so that when polished it presents a singularly pleasing ornamental appearance. The material is available in large spheroidal boulders ; and huge blocks could doubtless be obtained by blasting ; while the facilities for conveyance to Porbandar City as the principal centre of distribution are close at hand, in the Railway-siding to the extensive miliolite quarries adjoining.

Microscopical Determinations of the Mineral Units in the Spherulitic Felsite from the Adatiana Heights.

Under the microscope, thin sections present the appearances shown by the photomicrograph, Fig. 38, Plate XXXVI. From this it will be seen that the ground-mass is composed of a cryptocrystalline matrix of true felsite, *i.e.*, an intimate blending of felspar and quartz, the mineral units of which cannot be distinguished

* See Fig. 37, Plate XXXV.

PLATE XL.



Regd. No. 524.—Fig. 42.—Cleaved Granophyre.

Summit of Dhori Dhar, Foundations of State Bungalow,

Khambala Talav, Barda Hills.

Resolved by WATSON & SONS' 1 *inch Objective*, 0·21 *Numerical Aperture*.

Amplified 30 Diameters.

Almost the entire field of view is occupied by comparatively coarse micropegmatite **mp**, and patches of nearly ultramicroscopic micropegmatite, **mp'**. The cloudy grey-brown material, **O**, adjoining, is probably altered orthoclase and frequently shows rectangular reticulations. **A.A.**—An elongated porphyritic crystal of green augite, intergrown with colourless laths of sanidine, **S**, in ophitic fashion, and associated with crystals of opaque black magnetite. Magnetite, **M**, also occurs in form of minute octahedra, irregular grains and aggregates, **M'**, and linear or skeleton microlites **S.**—Small colourless laths of sanidine. **Q.**—Mosaics of water clear quartz.

when viewed by ordinary transmitted light, but which become apparent when the section is rotated between crossed nicols.

Nature of the Ground-mass in the Spherulitic Felsite from the Adatiana Heights.

It is mainly the ground-mass which serves to draw a sharp line of demarcation between the felsites and the group of granophyres ; for the ground-mass of the latter consists of a micropegmatitic intergrowth of felspar and quartz, readily discernible with ordinary light ; while polarised light serves to map out each separate unit by the simultaneous illumination or extinction of its component intergrown particles.

The ground-mass is still further diversified by the presence of numerous diminutive octahedra, irregular grains and spicular microlites of opaque black magnetite ; while small crystals and incipient rods of a green pyroxene are less frequently met with.

Intimate structure of the Spherulites in the Spherulitic Felsite from the Adatiana Heights.

Closely crowded in the ground-mass, are the spherulites, which endow the stone with its dark-spotted ornamental character. These spherulites exhibit an advance on the stage of development depicted by the spherulites of Fig. 5, Plate IV, inasmuch as they are generally formed around nuclei of phenocrysts of colourless sanidine, many of which are characteristically twinned. Under powers of about 50 diameters or more, the substance of the spherulites proper can be resolved to show that they are constituted by :—(*i*).—Radiating fibrils of brownish orthoclase felspar of the nature of that entering into the composition of the ground-mass and occasionally present as rectangularly reticulated interstitial patches, sometimes shown in optical continuity with the corresponding spherulite fibrils or incipient crystals. (*ii*).—Interlaced or parallel alternating fibrils of clear, colourless quartz, also sometimes shown in optical continuity with the quartz of the matrix or ground-mass, especially when the latter is present in interstitial situations. (*iii*).—Fibrous, radiating, indigo-coloured moniliform microlites or trichites of pyroxene, sometimes abundant and at others absent. (*iv*).—Small incipient laths or spicules of greenish pyroxene, like those observable in the ground-mass. (*v*).—Skeleton microlites in parallel and rectangular grouping, of grains or minute octahedra and rods of opaque black magnetite.

Colourless, but almost always containing inclusions of the ground

mass, the comparatively large, idiomorphic crystals of sanidine, which are frequently twinned,—as well shown by Fig. 37, Plate XXXV,—invariably furnish the nuclei around which the spherulites segregate. They are, in effect, phenocrysts that have taken definite crystalline form prior to the consolidation of the substance of the spherulitic bodies and the groundmass. Between crossed nicols they exhibit more or less clearly the polysynthetic twinning distinctive of triclinic felspars, and may therefore be regarded as intergrowths of principally orthoclase and a little plagioclase.

Sanidine Crystals in the Spherulitic Felsite from the Adatiana Heights

Other phenocrysts of a green colour, giving the cleavage angles of augite, are less frequently present in the form of elongated but sometimes tabular, hexagonal crystals, which occasionally exhibit ophitic structure as at A, Plate XXXIV; the endomorphs being of the nature of small colourless laths of sanidine, and associated separations of opaque black magnetite.

Pyroxenes in the Spherulitic Felsite from the Adatiana Heights.

Allusion has already been made to the presence of two other subsequent generations of pyroxene, found forming incipient spicular greenish crystals in the felsitic ground-mass and bodies of the spherulites, and of the indigo-coloured, sometimes moniliform, hair-like rods or trichites which contribute largely to form the substance of the spherulites. Very rarely,—as at E, Fig. 37, Plate XXXV,—partial separations of a negative and highly refractive, honey-yellow mineral obtain, which are probably of the nature of epidotised augite.

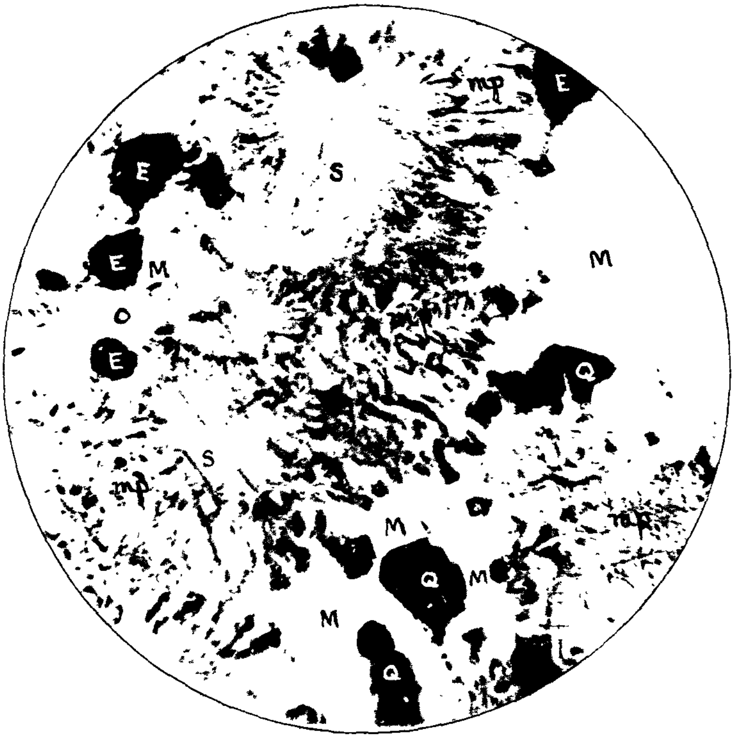
Anomalous Epidote in the Spherulitic Felsite from the Adatiana Heights.

In addition to the relative positions and forms already noted, the opaque black magnetite occurs disseminated throughout the field of view in isolated, but more frequently, aggregated well defined crystals. Even in the very thinnest possible sections, magnetite always remains opaque under transmitted light and of a slightly bluish-black colour when examined by reflected light; but SIR HENRY A. MIERS* records the fact that, Magnetite and hæmatite both occur as excessively thin dendritic deposits

Magnetite in the Spherulitic elsite from the Adatiana Heights.

* 'Mineralogy', London, 1902, p. 384.

PLATE XLI.



Regd. No. 536.—Fig. 43.—Altered Coarse Granophyre.

Base of E. Slope of Babia Dungar, Barda Hills.

Resolved by WATSON & SONS' $1\frac{1}{2}$ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

The initial power calculated for an image distance of 10 inches for this objective is only 8 diameters, but the image has then been amplified to the dimensions depicted above where the micropegmatite, **mp**, of the centric systems is very clearly defined. The felspar has been altered to a cloudy brown colour, and appears to be mainly orthoclase, with centric nuclei of sanidine, **S.** Interstitial quartz, **Q,** and felspars are also in evidence, and there are many very large aggregated, as well small isolated crystals, **M,** of magnetite. The pyroxene has vanished, leaving only traces of its former presence in a few rusty coloured patches and elongated forms. **E.**—Empty spaces.

in the cleavage laminæ of mica, where they may be sufficiently thin to be translucent '; ......while, ' In whatever form the mineral occurs, it may always be identified by its magnetism ; the only other mineral which possesses the property *in the same degree* is ferriferous platinum.'

Porphyritic Microcrystalline Felsite of Dhanak Dhar.

REGD. NO. 91.—The provisional name given to this specimen, as a basalt is incorrect*; for, by determinations in the laboratory, it has been found to be of pronounced hypabyssal origin, although to the naked eye the blue-black to pale-grey stone closely resembles a compact basalt. Thin sections under the microscope reveal a microcrystalline ground-mass, sparingly studded with groups or sometimes single phenocrysts of :—(*i*).—Carlsbad twins of grey orthoclase felspar often partially interpenetrating, and occasionally displaying well-marked rectangular reticulations. These frequently measure $\frac{1}{35}$ by $\frac{1}{50}$ inch in superficial dimensions. (*ii*).—Tabular and elongated crystals of green augite, $\frac{1}{80}$ by $\frac{1}{100}$ inch ; frequently inclosed and also intergrown with the felspar phenocrysts. (*iii*).—Opaque black magnetite, $\frac{1}{300}$ to $\frac{1}{200}$ inch across, partially inclosed by both augite and felspar, and also sparingly studding the ground-mass at irregular intervals. The rock may, therefore, be correctly called a ' Porphyritic microcrystalline Felsite.'

The ground-mass is constituted by a microcrystalline structure of minute irregularly shaped crystals, of quartz $\frac{1}{600}$ to $\frac{1}{700}$ inch, intergrown with equally small patches and ill-defined laths of greyish orthoclase, occasionally showing a tendency to micropegmatitic structure ; while a second generation of diminutive angular grains of green augite, $\frac{1}{500}$ to $\frac{1}{300}$ inch, and of mere specks and granules of magnetite are plentifully scattered throughout the field-of-view.

Felsitic Granophyre.

Transitional phases of structure, showing a ground-mass composed almost entirely of micropegmatite, *i.e.*, intimate crystalline intergrowths of felspar and quartz, but also exhibiting a few cryptocrystalline areas of true felsite, are well represented by the rock registered as No. 55, of which the photomicrograph of a typical thin section is given as Fig. 41 on Plate XXXIX. This rock has therefore been called a ' Felsitic Granophyre.'

By reason of the predominating presence of well-developed micropegmatite, this valuable stone, of a pleasing pale blue-grey colour,

* *Cf ut supra*, ' Narrative Report,' pp. xxv, xxvi ; also p. 13.

with patches of pink and light-red wherever it has been sunbaked for prolonged periods, ought to furnish invaluable building-blocks for dock and harbour construction ; while the wastage could be profitably utilised for high-grade road-metal.

It occurs as an outlier-spur from the mountain-massive, adjoining the Railway-line, about 3 miles ENE. of Ránáwáo Station, and extends along the plain in the form of a small range of hillocks nearly right up to the roadway leading from Ránáwáo town to the Naliadhar Jungle-reserve ; so that there is ample material available for an almost inexhaustible supply of stone ; while the range of hillocks offer an exceptionally favourable series of sites for quarrying operations on a large scale. This stone is being tested for heavy-traffic highways, as road-metal, by Karachi Municipality.

Microscopical Determinations of the Mineral Constituents in the Felsitic Granophyre.

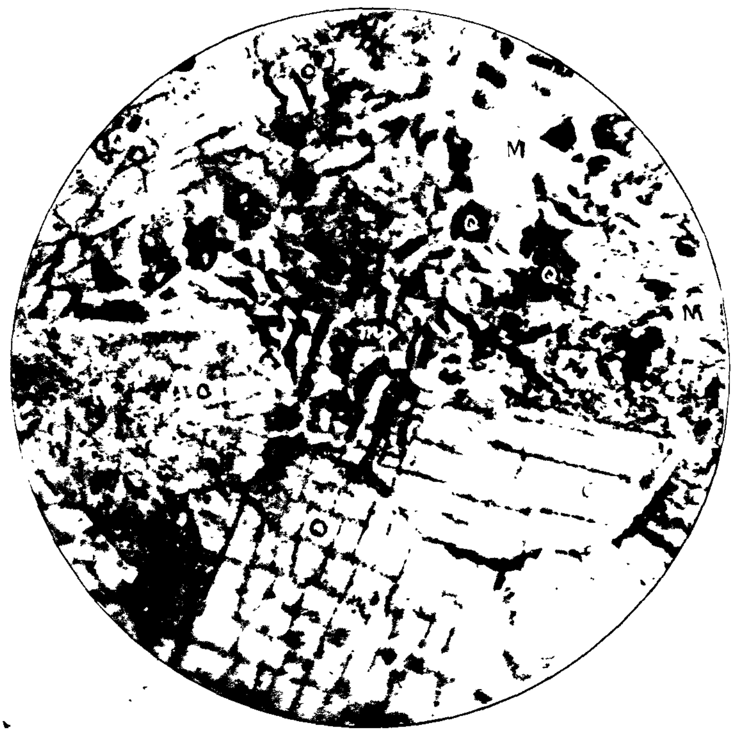
Under the microscope, the ground-mass is shown to consist, as already noted, almost entirely of well-formed micropegmatite with a few subordinate patches of cryptocrystalline felsite every here and there ;—these being traversed by moniliform rods and trichites of indigo-coloured pyroxene, and bearing a burden of spicular incipient crystals of green augite with separations of opaque-black magnetite and minute octahedra and skeleton microlites of the last-named mineral.

Incipient crystallisation is manifested by the presence of spherulites differentiated into centric systems of micropegmatite,—in place of the radiating fibrils distinctive of spherulitic felsites*—with nuclei of orthoclase felspar or its variety,—sanidine. A few idiomorphic colourless crystals of sanidine frequently occur, sometimes twinned on the Carlsbad law, and exhibiting simultaneous straight extinction ; and these occasionally, show traces of intergrowth with a triclinic felspar by their multiple lamellation when examined between crossed nicols.

Mosaics of interstitial quartz are plentifully present and point to secondary changes ; while the pyroxene,—in addition to the indigo-coloured moniliform microlites noted above,—is manifested by sub-idiomorphic tabular plates of green augite sometimes with ophitic endomorphs of colourless laths of sanidine and separations or associations of magnetite crystals of irregular shapes. Magnetite is also disseminated throughout the field-of-view in the form of minute, opaque-black octa-

* *Cf. ut supra*, Plates IV, XXXV, XXXVI and XXXVIII.

Plate XLII.



Regd. No. 536.—Fig. 44.—Altered Coarse Granophyre.

Base of E. Slope of Babia Dungar, Barda Hills

Resolved by Watson & Sons' 1 *inch Objective*, 0.21 *Numerical Aperture*.

Amplified 30 Diameters.

O.—Sub-idiomorphic, altered, cloudy, brownish-grey crystals of orthoclase occupying intermediate or interstitial positions with reference to the centric systems and showing rectangular reticulations with great clearness. **Q.**—Allotriomorphic quartz. Both the large felspars and quartz are shown in optical continuity with their counterparts constituting, **mp,** the coarse micropegmatite of the sparingly developed ground mass. **M.**—Isolated grains and irregular crystals of opaque, black magnetite.

hedra, irregular grains, skeleton microlites and aggregates of larger crystals.

Granophyres without any trace of a cryptocrystalline or felsitic matrix or ground-mass, and in which spherulitic structures have been developed into nucleated centric systems, each foreshadowing the formation of a complete crystal, are well represented by several noteworthy examples from the south-eastern quarter of the Barda Group of hills.

Typical Granophyre of Gadhia Dhar.

One of the most typical of this variety, has been registered as No 522, and forms the bulk of a large conical, partially isolated hillock called Gadhia Dhár, rising from the NE borders of the Khámbala Talav or reservoir at its dammed-up extremity, about 1,000 yards or so NNW. of the Khámbala State-Bungalow.

The stone is compact and closely textured ; of an originally fresh grey colour, but superficially sunbaked,—without loss of any of its physical properties,—to a purplish hue. The rock is exceedingly difficult to break with sledge-hammers, and proportionately difficult to tool ; but with modern appliances, ought to yield an abundance of ideally tough and strong, weather-resisting building-blocks, at reasonable cost capable of withstanding enormous crushing strain as well as severe attrition, and therefore adapted to the requirements of dock and harbour construction, road-making and wherever resistance to impacts and wear and tear is an indispensable condition.

Nucleated 'Centric systems' of the Gadhia Dhar Granophyre.

Although by no means of plutonic or abyssal origin, the Gadhia Dhár granophyre approaches very nearly to those rocks, by the absence of any ground-mass or matrix of itself, provided that the nucleated centric systems of micropegmatite, or intergrown felspar and quartz, are each regarded as separate crystal units. Binding these centric systems closely together there is a large proportion of coarser micropegmatite, composed of water-clear quartz, often segregated in patches of numerous allotriomorphic, differently orientated units, which interlock with similar patches of cloudy-brown orthoclase ; and this interstitial coarsely constituted micropegmatic, between coarsed nicols, may be seen to be in optical continuity with the micropegmatitic constituents of adjacent centric systems.

Curiously enough, the nuclei of the centric systems are mostly of the nature of independent idiomorphic crystals of clear sanidine, occasionally twinned on the Carlsbad law, and giving simultaneous straight extinctions when rotated between crossed nicols. Some of the nuclei, however, display an almost ultramicroscopic granophyric structure ; the brownish felspar,—orthoclase,—and water-clear quartz being optically continuous with their counterparts surrounding the centric systems. The cloudy, brown, interstitial orthoclase, moreover, when sufficiently developed exhibits well-marked rectangular reticulations.

Accessory Constituents of the adhia Dhar Granophyre.

Pyroxene is but sparingly present in this rock, being sporadically distributed in all parts of the field-of-view in two forms, probably representing distinct generations :—(*i*) —As bright green sub-idiomorphic sections, some of which show cleavage angles of 87°, arallel to the prism, and are usually associated with irregular aggregated opaque black crystals of magnetic iron-ore. (*ii*).—In the form of dusky green much elongated skeleton-laths or spicules frequently intergrown with minute grains of magnetite.

Magnetite, black, opaque and but seldom altered at its edges in weathered specimens also occupies a subordinate place, indiscriminately throughout the rock texture, in the form of minute octahedra, irregular grains often collected into comparatively large patches, and larger idiomorphic single or aggregated crystals. Although but an accessory, much of the magnetite is probably original ; but a goodly proportion doubtless arises through secondary separations from the pyroxenes.

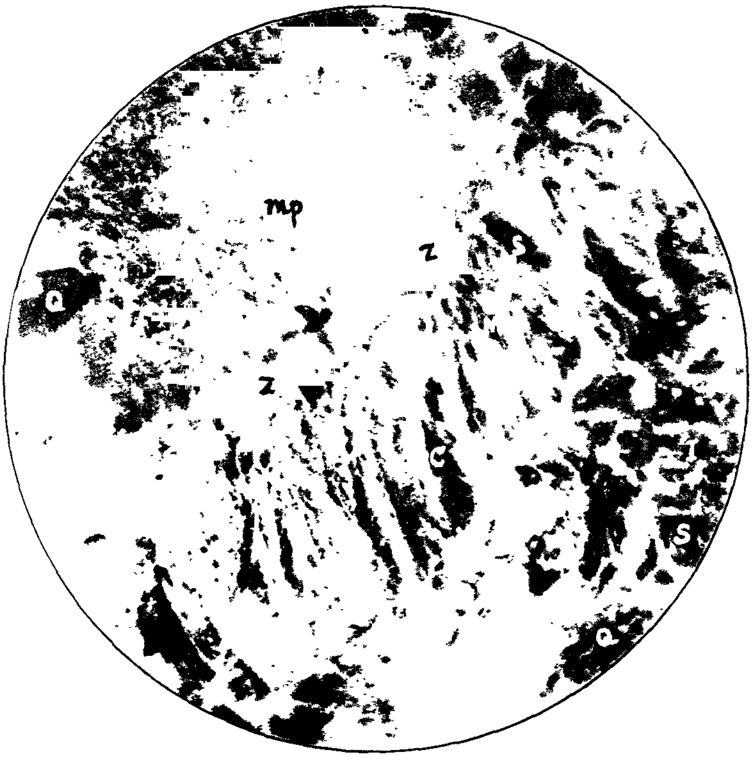
The Dhori Dhar Granophyre.

About 1,000 yards SSE. of Gadhia Dhár, and affording a magnificent view of the Khámbala Talav ensconsed by its amphitheatre of hills, there rises the summit of Dhori Dhár, on the platform of which the Khámbala State-Bungalow is perched. The rock forming this eminence consists of a pale bluish-grey granophyre of essentially similar structure to that of Gadhia Dhár, but it is diversified, especially at the summit, immediately beneath the bungalow, by much cleaved intrusions,—evidently, subsequent eruptions from the same molten ass of material.

These intrusions vary but slightly from the older dyke-rock* through

* *Cf postea*, p. 107.

PLATE XLIII.



Regd. No. 160.—Fig. 45.—Orbicular Granophyre.

Crown of Gured Dhar, a Spur from Dhorio Dhubho, Barda Hills.

1½ Miles ESE. by SE. from Godhana.

Resolved by WATSON & SONS' 1 *inch Objective*, 0·21 *Numerical Aperture.*

Amplified 30 Diameters.

Portion of an orbicular unit, showing nucleus, **mp**, of micropegmatite in intergrowths, each about $\frac{1}{500}$ inch across. **Z.**—Zone of almost ultra microscopic micropegmatite. **C.**—Celephitic selvage. **I.**—Interstitial area. **S.**—Small laths of sanidine. **M.** Placed below octahedron of magnetite. The micropegmatite of the nuclei is frequently of the nature of twin or else of an aggregate of units, as shown by the varied orientation of different parts between crossed nicols. **Q.**—Empty space.

which they were manifestly forced under conditions of great lateral pressure, and are typically represented in structural details by the sample registered as No. 524, under the corrected name of 'Cleaved Porphyritic Granophyre.'—Fig. 42, Plate XL.

Cleaved Porphyritic Granophyre from the Summit of Dhori Dhar.

Essentially built up of commingled areas of comparatively coarse and almost ultramicroscopic micropegmatite, there are many patches where the colourless quartz and cloudy brown orthoclase collect together in allotriomorphic forms, which, however appear in optical continuity with their counterparts in the micropegmatitic areas. Interspersed sporadically there are many small laths of colourless sanidine, most of which are simply twinned; and these also, together with crystals and grains of opaque black magnetite are frequently intergrown, in ophitic fashion with large elongated, practically porphyritic crystals of green augite. Augite also occurs in tabular idiomorphic and irregular sections of crystals, usually with inclosures of magnetite, while it sometimes forms elongated dusky-green incipient rods charged with numerous grains of magnetite. The latter moreover presents, in addition to crystal forms, sundry granular aggregates, and skeleton microlites, some of which are constituted by linear successions of diminutive octahedra. The orthoclase when well-developed shows rectangular reticulations.

Yet another advance in the development of the rich range of granophyric rocks of Porbandar State, is afforded by the prodigiously tough and strong stone found forming the bed and banks of the deep gorge of a mountain stream called Vijfaria Jhár, —an affluent to the great Khámbala Talav in the Barda Group of hills.

Sub-holocrystalline Granophyre of Vijfaria Jhar

The sample under consideration was taken from the bed of the Jhár, some 600 yards or so NNW. of the picturesque shepherds' retreat called Khara Virá Nes, and registered as No. 516, in the State Geological Collection.

When prepared as a thin section and examined in the laboratory, the discovery was made that the rock owes its extraordinary toughness to its peculiar intimate structure; being practically composed of units of well developed micropegmatite as the dominant constituent. (i).—These units, take the form of sub-idiomorphic crystals, after orthoclase, and consist of inter

Microscopical Determinations of the Mineral Constituents of the Vijfaria Jhar Granophyre

growths of greyish felspar and water-clear quartz. (*ii*).—Next in abundance come several well-formed colourless elongated laths and Carlsbad twins of sanidine, some of which show multiple twinning and are therefore evidently intergrown with a triclinic felspar. A few clear crystals of elongated habit, are so strongly twinned, with albite lamellation, as to prove the presenœ of an excess of plagioclase felspar in the obscure intergrowth. (*iii*).—There are several large patches and small spaces completely filled with differently orientated mosaics of water-clear quartz, and others with cloudy grey felspar, both of which are in optical continuity with their corresponding minerals which form the compound crystals of micropegmatite. Accessory constituents include :—(*iv*).—Dusky green pyroxene of elongated habit almost always laden with microlites and grains of opaque black magnetite. There are also crystals of probably a previous generation of tabular, brighter green augite. (*v*).—Minute octahedra, irregular grains, microlites and tolerably large aggregated crystals of magnetite disseminated throughout the substance of the structure. (*vi*).—Occasional irregular grains and sub-idiomorphic honey-yellow, highly refringent, monoclinic crystals of probably an abnormal variety of epidote. Under high powers the quartz patches may be seen to exhibit negative crystals, and strings of diminutive cavities and adventitious particles. Upon these data the rock has been named, by the writer, a 'Sub-holocrystalline Granophyre.'

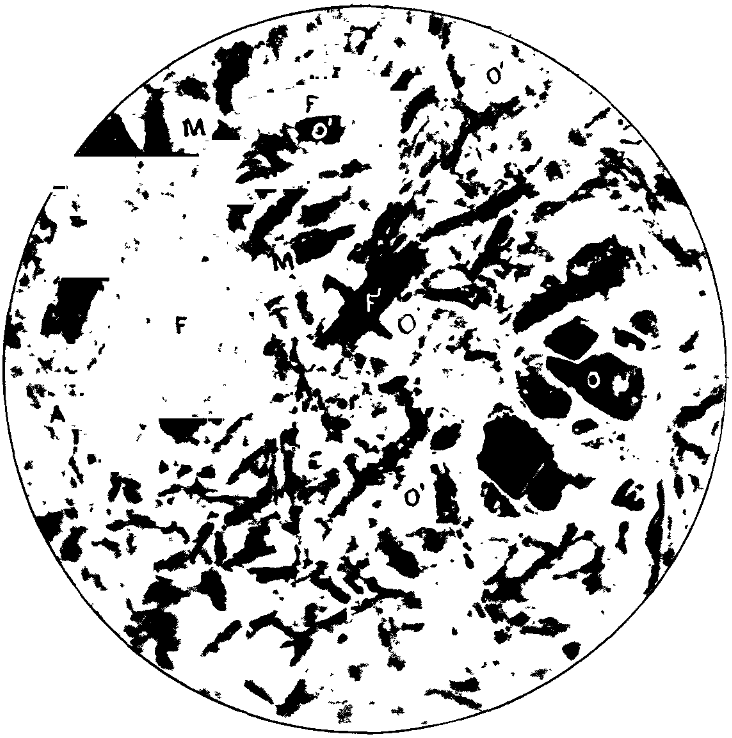
Curiously Altered Granophyre of Vijfaria Jhar.

Curiously enough this sub-holocrystalline granophyre only undergoes alterations, due to alternate sunbaking and monsoon conditions, sporadically ; but the external appearance of these restricted areas, is simply startling; for the mass, originally of a dark brownish-grey colour, changes to a rosy hue, mottled with white patches. If anything, the altered is only slightly less hard than the fresh rock.

Microscopical Determinations of the Mineral Constituents in the Altered Granophyre of Vijfaria Jhar.

When viewed under the microscope, thin sections of this specimen, registered as No. 517, may be seen to preserve the sub-holocrystalline character of its micropegmatitic idimorphic crystal-units ; but, while the felspathic elements of both micropegmatite and well-formed crystals of sanidine are more or less deeply indued with red iron-oxide,—probably of the nature of ferric hydrate,—the micropegmatitic quartz and interstitial mosaics of the same mineral remain intact. Most of the magnetite, moreover, with the exception of a few of its larger units, and all traces of the

PLATE XLIV



Regd. No. 223. Fig. 46. —Hypocrystalline Olivine-Basalt.

Hilly-mound, 2½ miles NE. of Morwara.

Resolved by WATSON & SONS' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

F.—Phenocrysts of plagioclase felspar,—medium to basic labradorite.

F'.—Ground-mass laths of plagioclase felspar,—medium to acid labradorite.

A.—Irregular grains and small tabular crystals of greenish purple-brown augite.

O.—Phenocryst of olivine, rich in iron, with red-brown borders and cracks.

O'.—Second generation of olivine, deeply margined and indued with red iron-oxide.

M.—Small grains of opaque black magnetite and larger aggregates of, probably, titanomagnetite.

No interstitial residue of isotropic glass is here shown, but small patches of colourless to faint brown unindividualised glass occur, often in intersertal positions in other parts of the same preparation.

pyroxene appear to have vanished. The rock has accordingly been named an 'Altered Sub-holocrystalline Granophyre.'

Coarsely-textured Character of the Rocks forming the 'Heart of the Hills.'

The 'heart of the hills,' constituted by the sub-mountainous summits and slopes of Bábia Dungar, Káládongar and stretching away westward *viâ* Sathvirda Nes to the lofty heights of Málak Dungar, etc., is mainly built up of enormous masses of somewhat coarsely-textured granophyres, liberally intersected by cleaved dykes. The surface of the stone is everywhere so deeply weathered, that fresh samples can only be secured by blasting; but it was with the utmost difficulty that specimens of tolerably sound and only partially altered rocks were gathered, from which to arrive at a correct conception of their true nature.

Altered Coarse Granophyre of Babia Dungar.

Typical of these samples, is the one, called an 'Altered Coarse Granophyre,' which, in its perfectly fresh condition, is of a grey colour; but, by a process akin to laterisation, or the reactions of prolonged alternate sunbaking and monsoon conditions, becomes converted into an opaque milk-white rock, full of miarolitic spaces, and conspicuous large segregations of opaque black iron-ore.

Even in its altered condition the rock is very tough and hard; but when quite fresh, is, perhaps, one of the strongest of natural products in existence. It is therefore unfortunate, that where such an abundance of valuable building-material occurs,—favourably situated for quarrying operations on a large scale,—the sites should at present be inaccessible.

The Fresh-grey Granophyre of Sathvirda Nes.

Only a few typical samples were taken, to show the character of the practically sound rock, registered as a medium-textured grey granophyre, No. 520, from a prominent ledge, 500 yards ENE. of Sathvirda Nes; and the altered specimen of coarse granophyre, already noted, taken from the base of the eastern slope of Bábia Dungar;—of which Fig. 43, Plate XLI, is the photomicrograph of a thin section.

Microscopical Determinations of the Mineral Constituents of the Altered Coarse Granophyre of Babia Dungar.

From the picture, it will be observed, that the mass consists essentially of large nucleated centric systems of coarse micropegmatite, the intergrown felspar and quartz components of each of which, extinguish simultaneously, and give an average measurement of about $\frac{1}{100}$ inch. The nuclei of these arrested crystal-forms is generally of the nature of sanidine; while the felspar

components of the micropegmatite, which are shown in Fig. 44, Plate XLII, from another part of the same preparation, are seen to be in optical continuity with the felspar forming large allotriomorphic interstitial crystals, and probably of the nature of ordinary orthoclase, exhibiting rectangular reticulations with great clearness.

Kaolin and Kaolinite.

All of the felspars happen in this instance to have undergone profound changes into a semi-opaque milk-white substance which in very thin sections under the microscope exhibit a brownish-grey cloudy appearance, and doubtless heralds the breaking down of the mass into kaolin ;—usually formed by the re-crystallisation of the decomposed alkaline felspar units, into microscopic colourless scales, hexagonal tablets and monoclinic crystals of kaolinite.

The water-clear quartz, both of the micropegmatitic and coarser interstitial areas, is invariably crowded with air-cavities, irregular and linear strings of inclusions of the original molten magma and clear rod-like crystallites of undeterminable composition. It remains in a perfectly fresh and unaltered condition, and the interstitial sub-idiomorphic crystals may be clearly seen to be in optical continuity with the quartz of the micropegmatite, and that of the fine lines which serve to indicate twinning planes in the altered sanidine (S. at centre of Fig. 43), and the rectangular reticulations of the interstitial orthoclase.

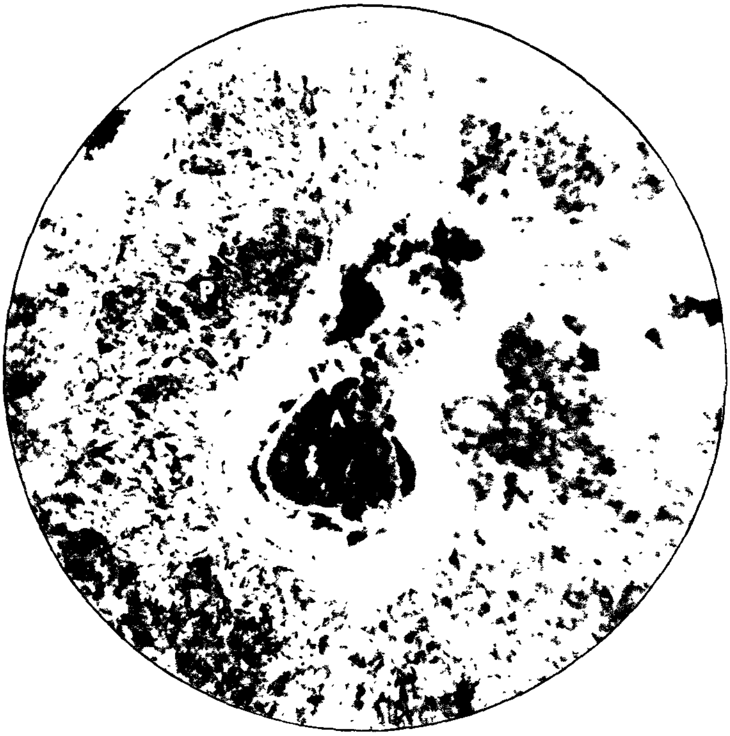
Segregations of Iron-ore in the Altered Granophyre of Babia Dungar.

In the unaltered specimens the magnetic iron-ore is disseminated throughout the mass in forms of minute octahedra, irregular grains, skeleton microlites and isolated or aggregated opaque black crystals of tolerably large sizes ; but, in the altered rock from Bábia Dungar, only a few isolated crystals can be detected in their normal relative positions, the bulk of the mineral having segregated to produce large well-formed patches of iron-ore, so compactly and closely developed, that it might be profitable to crush the stone for iron-smelting and utilise the residue for the fashioning of pottery.

Altered Granophyres of Kari Dhar and Jaderra Dhar.

Similar stone, altered to a milk-white colour and hardened by sun-baking, but without the separation of iron-ore, occurs in superabundance at the easily accessible sites, known as Kári Dhár on the S. side of Khámbala village, and along the plain leading to and including a couple of outlying hills called Jaderra Dhár,

PLATE XLV.



Regd. No. 542.—Fig. 47.—Altered Amygdaloidal Basalt.

10 feet below surface of Well shaft, 1½ miles

NE. by NNE. of Asiapat, Barda Hills.

Resolved by WATSON & SONS' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

A.—Compound amygdale formed by the coalescence of two vesicles, and filled with a variety of alteration products, probably due to thermal metamorphism. **P.**—Faint indications of aggregates of felspar phenocrysts. **G.**—Andesitoid ground-mass.

which are situated but 2 miles NNW. of the village of Bordi, where it is again recommended that a Railway Station or at least a loading platform ought to be erected, if it is desired to utilise the rich range of economic stones of the south-eastern slopes, spurs and outliers of the Barda Group of hills.

Kaolinisation and the Production of 'China-clay.'

These altered alkaline-felspar rocks, which appear, under the microscope to have undergone the first stages of kaolinisation, it is here suggested, might by artificial processes be made to profitably yield unlimited supplies of the so-called "China-clay," for the manufacture of porcelain.

Lastly, to return to the examination of the Bábia Dungar Altered Granophyre :—By diligent searching, a few small fragments of green pyroxene and honey-yellow abnormal epidote may be detected; but the dusky-green laths and elongated rods of pyroxene, so freely found in kindred specimens, are here only evidenced by rusty-coloured traces of their former existence in the unaltered rock-mass.

Orbicular Granophyre of Gured Dhar near Godhana.

Unique among the granophyres of Porbandar State, and probably the only hitherto discovered example of its kind extant, is the rock registered as No. 160, under the style of an 'Orbicular Granophyre', which occurs as a secondary spur, called Gured Dhár, emanating from the spur known as Dhorio Dhubho, at the extreme western flanks of the Barda Group of hills;—approximately $1\frac{1}{2}$ miles ESE. by SE. from the village of Godhána.

Napoleonite, Corsite or Ball-diorite of Corsica, and Orbicular Granites of Sweden, Ireland and America.

The rock is intensely tough and being deeply weathered at the surface, perfectly fresh material can only be secured by blasting. Hand-specimens, highly polishable, present the rare appearance known as *orbicular structure*, which was originally discovered in the napoleonite, corsite or ball-diorite of Corsica, and subsequently in some of the granites of Sweden and Ireland* but no instance, up to the present, has been recorded of its occurrence in hypabyssal rocks.

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* W. C. BRÖGGER and H. BÄCKSTRÖM, *Geol. Fören. Stockholm*. 1887, ix. p. 307; F.H. HATCH, *Q. J. G. S*, 1888, xliv, p. 548; A. HARKER and J. E. MARR, *Q J. G. S*. 1891, xlvii, p. 280; H. BÄCKSTRÖM, *Geol. Fören. Stockholm*, 1894, xvi. p. 107; B FROSTERUS, *Bull Com. Géol. Finland*, 1896, No 4; F. D. ADAMS, *Bull Geol Soc. America*. 1898, ix, p. 163.

Orbicular Regarded as an Advanced Development of Spherulitic Structure.

In this instance the orbicular is manifestly an advanced development of the spherulitic structure already illustrated by the varieties of spherulitic felsites and granophyres in the foregoing pages. The compound units in this case attain to comparatively large dimensions, averaging about $\frac{1}{3}$ inch in diameter.

Highly Ornamental Character of the Orbicular Granophyre.

Each unit is in reality a somewhat complicated structure, as will presently be proved in the sequel. It exhibits to the naked-eye a white core of sub-circular, sub-ovoid or polygonal outlines, surrounded by a dark, almost black, and tolerably wide border. These individuals are very closely crowded together, so as to leave but small interspaces, which are filled with a whitish-grey material; so that when cut and polished in any direction, a uniform and highly ornamental annulated surface can be secured.

Specific uses of the Orbicular Granophyre.

There can be no doubt, that by careful blasting, large blocks of the material can be extracted, suitable for the manufacture of occasional table-tops, mantelpieces, clock-cases, caskets, vases and the like; and these, which would be unique of their kind, ought to fetch fancy prices in the leading stone markets of the world.

When examined under the microscope, each *compound unit* presents the structure shown by the photomicrograph, Fig. 45, Plate XLIII, which has been magnified to display its essential details to the best advantage, as follows:—

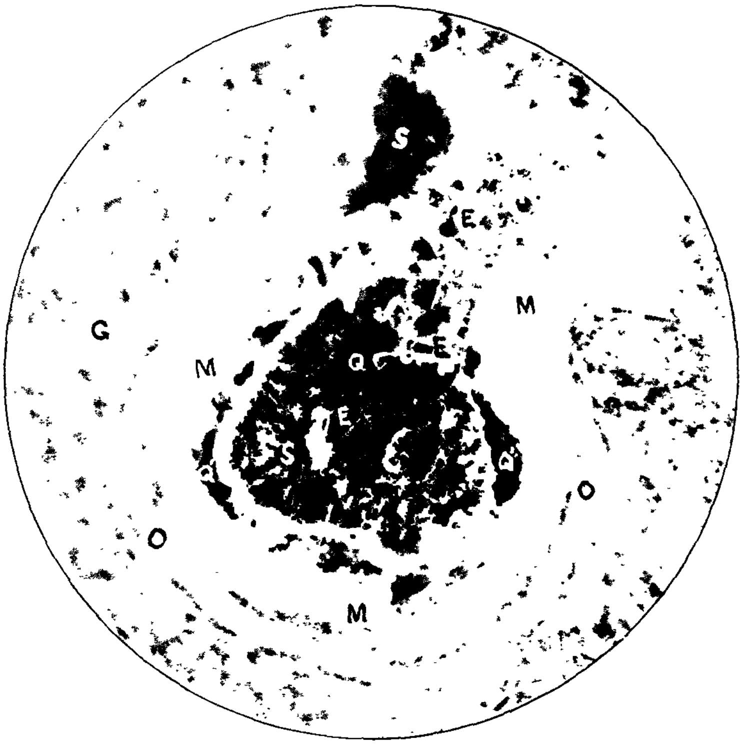
Microscopical Determinations of the *Mineral Constituents* of the Orbicular Granophyre.

Each orbicular system consists of a core or nucleus of tolerably fine micropegmatite, the intergrown components of which give a mean measurement of $\frac{1}{200}$ inch; and between crossed nicols extinguish simultaneously over only restricted areas, thereby showing the nucleus to be originally formed from a twin crystal or an aggregate of crystals of probably sanidine.

Micropegmatitic Nuclei with Celyphitic Selvages in the Orbicular Granophyre

The nucleus, which usually assumes sub-angular outlines, is surrounded by a zone, averaging about $\frac{1}{80}$ inch in width, and resolvable into excessively fine, almost ultra-microscopic radiating fibrils of felspar and quartz, many of which penetrate into an outer zone, varying from about $\frac{1}{33}$ to $\frac{1}{25}$ inch in breadth, and augmented

PLATE XLVI.



Regd. No. 542.—Fig. 48.—Altered Amygdaloidal Basalt.

To show the Intimate Structure of an Amygdale.

Resolved by WATSON & SONS' 1 *inch Objective*, 0·21 *Numerical Aperture*.

Amplified 30 Diameters.

G.—Ground-mass. **O.**—Outer sub-ultramicroscopic border of evidently a granular segregation of colourless *augite, (diopside)*. **M.** *Zone of aggregated* microlites of magnetite. **Q.** in continuity with **Q'**. Sub-central and zonal mosaics of colourless chalcedonic silica. **S.**—Pale, sea-green zonal patches of non-pleochroic material, exhibiting radiating fibrous structure between crossed nicols. **E.**—Monoclinic laths of pale-yellow epidote.

by numerous radiating, fan-like, branched bundles of moniliform rods and curved fibres of a dark brown to deep indigo colour. Some of these rods coalesce to form slender elongated crystals of a greenish colour, and all of these evidences supported by observations on the spherulites of kindred textures, are strongly in favour of the assumption that they are in reality incipient forms of pyroxene.

It is this outer zone or 'celyphitic' selvage, that endows the mass with its characteristic dark-ringed patterns when slices of the rock are cut and polished; and they must be regarded as of original and not secondary origin, such as the 'reaction-rims' found in many gabbros.

Subordinate Interstitial Ground-mass in the Orbicular Granophyre.

The orbicular like some of the smaller spherulitic and centric systems, in this particular specimen, are so closely crowded as to leave only comparatively small intermediate areas of the ground-mass visible; but in these situations the micropegmatite is generally more coarsely textured; while small laths of sanidine, larger blebs of quartz and irregular forms of green augite make their appearance. Opaque black magnetite, in a fresh condition, even in partially weathered sections, occur in the restricted ground-mass and particularly in the celyphitic selvage in the form of irregular grains and minute octahedra which average about $\frac{1}{150}$ *inch in* diameter.

Economic Hypabyssal Rocks from Easily Accessible Sites in Porbandar State.

These determinations would be sadly deficient, if no record were to be made of some of the more important economic hypabyssal rocks that are at present available in large quantities from easily accessible sites; and the following brief list is therefore here submitted for the information and guidance of prospective prospectors and contractors:—

Grey Granophyre of Khoria Dhar on the Adatiana Heights.

REGD. NO. 33.—Chemically analysed*, is partially weathered at the surface, but even then remains exceptionally tough and strong and suitable for dock work. When quite fresh, is of a fresh grey colour, and consists of a slightly porphyritic, medium textured granophyre, occurring in tolerable abundance, in form of a nether hillock called Khoria Dhár, at about the limestone limit on the Ádatiána Heights, 100 yards or so E. of the Railway-siding, opposite "Navri" miliolite-quarry, No. 62.

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* *Ut supra*, p. 94.

Grey Granophyre of Gudazali Dhar on the Adatiana Heights.

REGD. NO. 127.—Is precisely similar to No. 33, and probably a continuation of the same intrusive mass. It is exposed as a spur, named Gudazali Dhár, from Gudazali Dungar, opposite miliolite-quarry No. 4 and adjoins the Railway-siding to the Ádatiána Heights, with a fairly deep gully intervening. By blasting, large quantities of perfectly sound building blocks could readily be secured. The bed of the gully, gives a fine exposure of spherulitic felsite of the variety No. 34, already described and illustrated.*

Ruddy-grey Sub-holocrystalline Granophyre below Mohr Chupra Dungar on the Adatiana Heights.

REGD. NO. 38.†—Occurs in vast quantities of huge boulders covering a very wide area over the limestone limit at the base of Mohr Chupra Dungar, and adjoining the Railway-siding to the miliolite quarries on the Ádatiána Heights. It may be described as a medium to finely textured 'Ruddy-grey, Sub-holocrystalline Granophyre';—its colour being manifestly due to sunbaking and alternate monsoon conditions; but is nevertheless, in the bulk of the large boulders from the lofty crags above, tough and strong enough for all building purposes and may even be used with satisfaction for dock-work, the erection of piers for bridges, as well as for high-grade road-making. This rock has already been largely drawn upon for the sake of the silica it contains for the manufacture of cement by THE INDIAN CEMENT CO., LIMITED, at their Porbandar works.

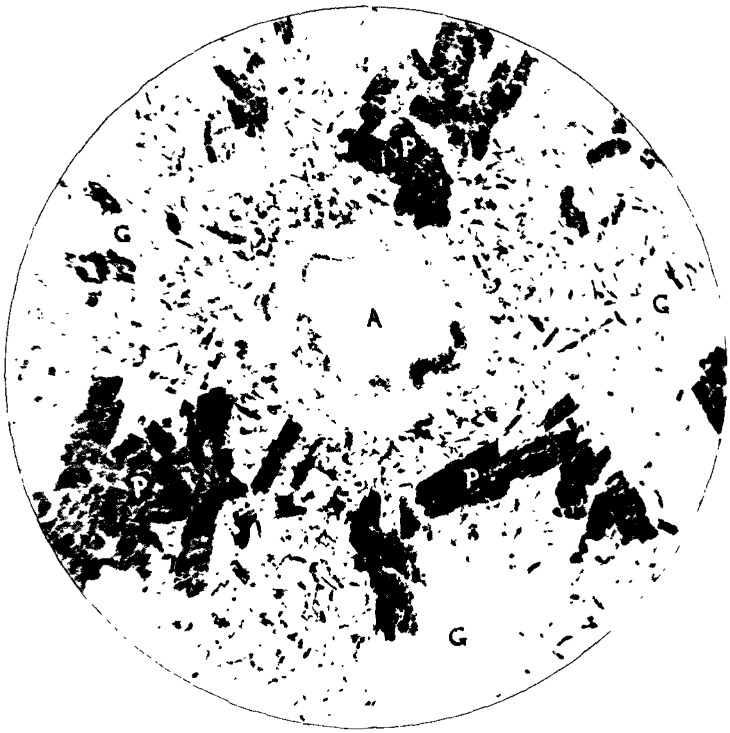
Highly Ornamental Holocrystalline Granophyre Erratic Blocks on the Adatiana Heights.

REGD. NO. 39.—Found occurring as huge erratic blocks and boulders, evidently detached from the steep heights to the NW. of Mohr Chupra Dhár and scattered thickly by the borders of the Railway-siding to the Ádatiána Heights adjoining miliolite-quarry, No. 158; this specimen closely resembles a red granite of from medium to coarse texture, and when polished furnishes ornamental material of great beauty. Under the microscope however, its true nature is instantly revealed as a 'Holocrystalline Granophyre'; being composed principally of allotriomorphic twinned crystals of pink and red orthoclase intergrown with quartz in micropegmatitic fashion; occasional idiomorphic units of colourless sanidine, irregular patches of water-clear quartz, and accessory small crystals of deep-green augite and opaque black magnetite. Sometimes,

* *Ut supra*, pp. 100-103; Plates XXXVI-XXXVIII.

† For chemical analysis, see 'Narrative Report', p. cxxviii.

PLATE XLVII.



Regd. No. 543.—Fig. 49.—Altered Porphyritic Basalt.

12 feet below Surface of Well-shaft.

1½ miles NE. by NNE. of Asiapat, Barda Hills.

Resolved by WATSON AND SONS' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

A.—Amygdale. **P.**—Glomero-porphyritic phenocrysts of triclinic felspar,—medium labradorite. **G.**—Andesitoid ground-mass, composed of:—(*i*).—Diminutive laths of triclinic felspar, simply twinned,—acid labradorite verging on andesine. (*ii*).—Densely packed microlitic granules of colourless augite,—diopside. (*iii*).—Microlitic granules and aggregated granules of opaque black magnetite. (*iv*).—A very small quantity of residual, greyish, isotropic glass.

the augite and magnetite occur in excess, and thereby give to those parts of the rock-mass, a glistening blackish colour flecked with red.

Sub-holocrystalline, almost Ultramicroscopic Granophyre, Adjoining the Ranawao-Bordi Cart-road.

REGD. NO. 47.—In hand-specimens, closely resembles a light to dark blue-grey, sparingly porphyritic dolerite; but, when examined under the microscope, turns out to be a 'Sub-holocrystalline, almost Ultramicroscopic Granophyre.' The allotriomorphic units of excessively fine micropegmatite constitute the bulk of the mass, and can only be satisfactorily resolved by a $\frac{1}{2}$ inch objective and amplification of over 50 diameters. Every here and there, segregations of allotriomorphic, water-clear quartz with a little cloudy grey felspar, form patches of a variety of coarser micropegmatite; while at irregular intervals there appear elongated porphyritic crystals, occasionally in Carlsbad twins giving straight extinction, of colourless sanidine. Accessory minerals, which give to the rock its dark colour consist of sporadic crystals of deep green augite crowded with grains of magnetite; a second generation of elongated, narrow rods of dusky-green augite also containing granules of magnetite; and an abundance of irregular crystals, skeleton-crystals and minute octahedra of opaque-black magnetite scattered throughout the field of view.

The stone is exceedingly hard, but not quite so tough as the slightly coarser varieties of granophyre. It is of course vastly stronger and more enduring than any volcanic rock, and most favourably situated for quarrying operations, being exposed as an outlying mound, about $2\frac{3}{4}$ miles NE. of Ránáwáo town, and again outcropping in greater abundance, to form the bed and high bank of a stream a little farther SE., skirting the cart road from Ránáwáo to Bordi, and forming part of the boundary of the Naliádhár State-jungle Reserve.

Grey-brown Holocrystalline Granophyre, 3 miles NE of Ranawao Town.

REGD. NO. 62.—Provisionally called a 'Grey-brown Light-coloured, Medium-textured Granophyre', and most favourably situated by the Bordi road-side only 3 miles NE. of Ránáwáo town, this exceedingly tough and strong stone occurs in form of a long and tolerably wide spur from the mountain-massive, trending from NW. to SE., to vanish at the surface immediately N. of the Naliádhár State-jungle Reserve.

When blasted, the rock presents a dark grey hue, but is very deeply weathered, and shows numerous superficial miarolitic cavities and patches

of yellowish-green decomposition products ; but, in spite of all this remains exceptionally strong and well adapted for breaking into road-metal of the highest grades.

Under the microscope it presents a typical holocrystalline texture, constituted by units of well-formed micropegmatite, in all essentials corresponding to the description given of the Vijfaria Jhar granophyre,* save that it is deficient in sanidine crystals. The stone has been recommended for dock and harbour work and road-engineering operations, and is one of the specially chosen samples now being tested for highway macadamising by Mr. MEASHAM LEA, the Chief Engineer of Karachi Municipality.

Finely-textured Porphyritic Granophyre of Dhori Dhar near Khambala.

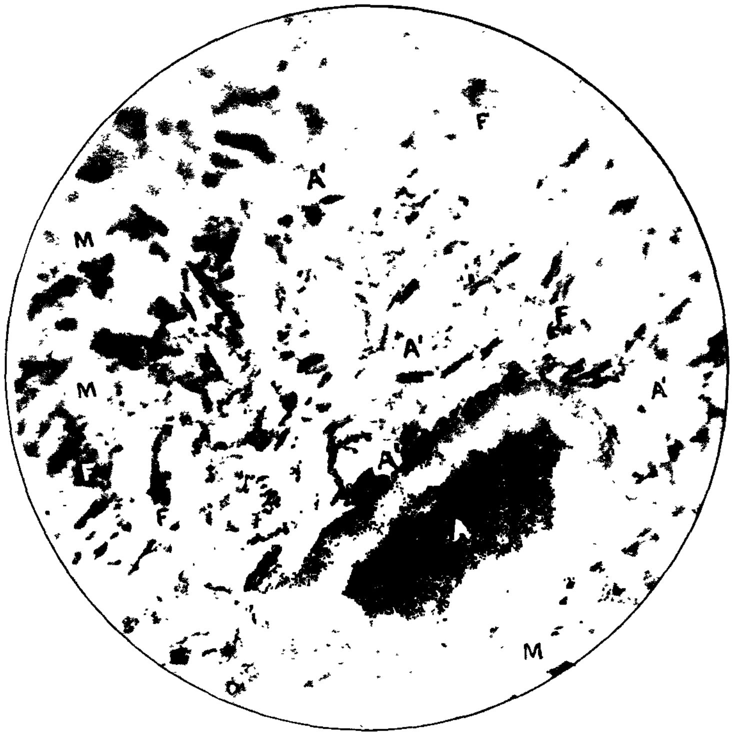
REGD. NO. 523.—Forming the bulk of the summit hill called Dhori Dhár upon which the Khámbala State Bungalow is built, and closely resembling the cleaved intrusions by which it appears to be intersected, this specimen exhibits a fresh, pale blue-grey, compact ground-mass, liberally studded with small porphyritic crystals. No trace of spherulites nor centric systems can be detected under the microscope, for the entire ground-mass is constituted by a variably fine micropegmatite of brownish-grey orthoclase and clear quartz in inter-growths of from $\frac{1}{400}$ to $\frac{1}{200}$ inch on an average. The porphyritic crystals, comprise tabular and elongated sections of green augite with inclusions of magnetite, and small idiomorphic crystals of colourless sanidine, sometimes twinned on the Carlsbad law and occasionally showing traces of polysynthetic twinning between crossed nicols.

Patches of dusky-green and incipient spicular crystals of augite, crowded with granules of magnetite, diversify the field of view, which further shows irregular areas of allotriomorphic water-clear quartz ; while minute octahedra and granules of opaque-black magnetite are plentifully distributed throughout the field of view.

From the foregoing determinations, this rock may now be correctly designated a 'Finely-textured Porphyritic Granophyre.' It is available, even at the surface, in a perfectly sound and fresh condition, and admits of being blasted to yield building blocks of large dimensions, while the wastage could be profitably utilised for high-grade road-metal.

* *Cf. ut supra*, p. 107.

PLATE XLVIII.



Regd. No. 306.—Fig. 50.—Fissile Amygdaloidal Basalt.

Well-shaft, 1 mile W. by WSW. of Morwara.

Resolved by WATSON AND SONS' $\frac{1}{2}$ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

A.—Amygdale of finely fibrous zeolite, formed of a dark brownish crenulated border and lighter grey core of radiating fibrils. **A'.**—Patches of aggregated granules of brownish augite. **F.**—Small colourless laths of triclinic felspar, many of which show multiple twinning. **M.**—Crystals and grains of opaque, black magnetite. In other parts of the same preparation there are a few somewhat larger laths of felspar phenocrysts,—medium to basic labradorite; while under low magnifying powers, the substance of the stone appears to be arranged in alternately dense and less compact layers which probably account for the fissility of the rock.

Finely-textured, Sub-porphyritic Granophyres of Cocachia Dhar near Bordi.

REGD. NOS. 113 AND 79.—About $1\frac{1}{3}$ miles SE. by SSE. of the village of Bordi, there is an outlying hill called Cocachia Dhár, which appears to be composed of a few separate dykes of granophyric rock of fine texture. These dykes, which are essentially similar in intimate structure, vary somewhat in their mode of occurrence, and megascopic appearance. No. 79 is exposed as a spur from the W. flank of the hill, and yields blocks of uniform texture, large dimensions, and a fresh light grey colour ; while No. 113, adjoining on the slope of the NW. spur of the hill, is almost black and cleaved into rectangular blocks of the size of extra large paving-setts.

Under the microscope No. 113, displays a field of view constituted by a tolerably fine-textured micropegmatite or intergrowth of light brown orthoclase felspar and clear quartz ; while patches of allotriomorphic larger crystals of quartz occur every here and there.

Between crossed nicols the micropegmatite shows traces of differentiation into allotriomorphic crystals after orthoclase, and these may be regarded as virtually forming a holocrystalline texture. Small porphyritic crystals of idiomorphic, colourless sanidine are sparingly present, sometimes as Carlsbad twins and frequently also showing traces of albite lamellation. Patches and grains of green augite, crowded with opaque black magnetite, are freely developed ; while minute octahedra and irregular crystals and granules of magnetite are so plentifully present as to endow the rock-mass with its black colour.

Need for a Railway-station or Loading Platform-siding at Bordi.

The Cocachia Dhár rocks may therefore be correctly called, 'Finely-textured Sub-porphyritic Granophyres' ; and, being admirably adapted to the wants of bridge, dock and road engineers, and most favourably situated for continuous quarrying operations, ought, if once introduced, to speedily find high favour in the markets of Western India. Unfortunately the present cartage expenses to Porbândar would be prohibitory for road-metal ; and it is therefore once more suggested that a strenuous effort should be made to establish a Railway Station, or at the very least a loading platform near the adjacent village of Bordi.

Finely-textured Porphyritic Granophyre of Dhordi Dhar near Bakharla.

REGD. NO. 120.—A pale bluish-grey, appreciably porphyritic and very finely textured stone, to the naked eye ; intensely hard, tolerably tough, and capable of being easily extracted by blasting from sites admirably adapted for quarrying on a large scale, this desirable rock occurs in

the form of a long nether hill at the base of the mountain-massive, called Dhordi Dhár, to the very foot of which a wide and well-beaten cart-track leads from the village of Bákharla, 4½ miles distant, to the WSW.

Microscopical examinations of thin slices are sufficient to demonstrate that the rock should be described as a 'Finely-textured Porphyritic Granophyre' constituted by :—(*i*).—A ground-mass of almost ultramicroscopic micropegmatite requiring a good ½ inch objective for its resolution, into an intimate intergrowth of light grey orthoclase and water-clear quartz. (*ii*).—Segregated patches of larger units of colourless allotriomorphic quartz. (*iii*).—Porphyritic, idiomorphic crystals of colourless sanidine mainly of elongated habit. Some of these crystals show twinning on the Carlsbad law, as well as traces of multiple lamellation indicative of intergrowths with a triclinic felspar. In a few instances the crystals are zoned ; being composed of a core of plagioclase enveloped by sanidine, and showing numerous intermediate inclusions of the fine micropegmatite of the ground-mass. Nearly all of the porphyritic crystals of sanidine are also crowded with inclusions of micropegmatite ; while occasionally there may be detected microlitic endomorphs of colourless, acicular, transversely-cracked, rods of probably apatite, which extinguish straight when rotated between crossed nicols. (*iv*).—Augite of a green colour is represented by sporadic, irregularly contoured, comparatively large patches, closely crowded with grains of magnetite ; and with evidently a second generation of small rod-like, dusky green crystals, also associated with magnetite granules. (*v*) —Opaque black magnetite also occurs disseminated throughout the substance of the stone in innumerable minute octahedra and crystal aggregates ranging from about $\frac{1}{1000}$ to as much as $\frac{1}{200}$ inch in mean diameter.

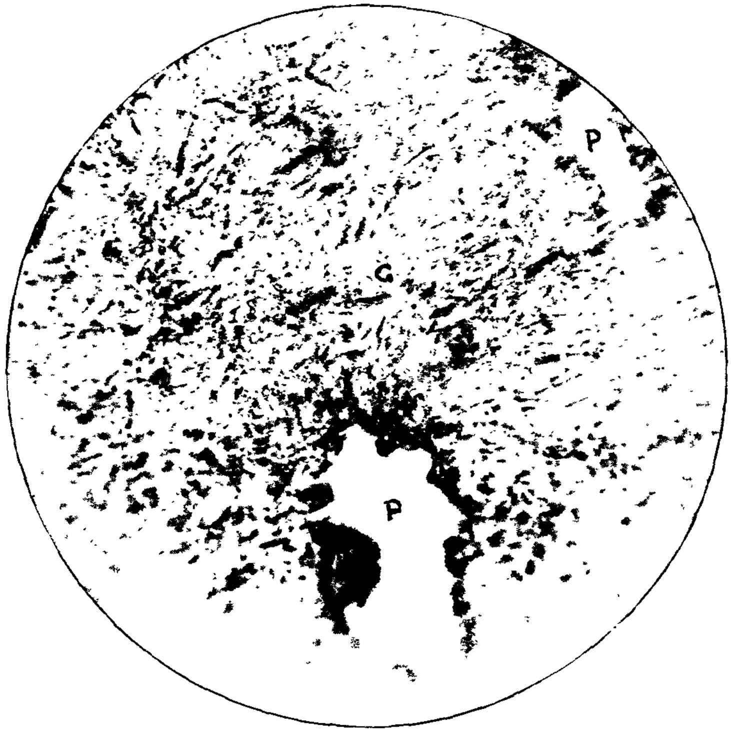
Incoherent Sand :—Decomposed Granophyre or Felsite, from Cave called 'Jambuvanti Bhoira.'

REGD. NO. 30.—Incoherent Sand, the mode of occurrence of which has already been recorded* has been chemically analysed† and found to tally closely in composition with the granophyres of the mountain massive. It is therefore assumed that the material is nothing more nor less than a thoroughly 'Decomposed Granophyre,' physically altered beyond recognition, but manitaining the integrity of its proximate principles.

* *Vide ut supra*, p. 49.

† *Ut supra*, p. 94.

PLATE XLIX.



Regd. No. 256.—Fig. 51.—Highly Altered Compact Basalt.

Ten feet below Surface of Well-shaft. 25 yards SW. of Bhavpura.

Resolved by WATSON AND SONS' ½ *inch Objective*, 0·34 *Numerical Aperture*.

Amplified 50 Diameters.

This rock furnishes a rare instance of chemical metamorphism, occasioned by the percolation of both salt and fresh water through beds of Dwarka shell-sand to react upon the beds of lava below. **G.**—Ground-mass, constituted by (*i*).—Excessively minute laths of triclinic felspar,—basic labradorite. (*ii*).—Aggregated granules of greyish to colourless augite. (*iii*).—Minute octahedra and irregular grains of opaque, black magnetite. (*iv*).—An appreciable amount of interstitial, residual, isotropic, colourless glass. **P.**—Elongated, irregularly shaped spaces, filled with a feebly refringent green alteration product. It is suggested that these represent metamorphosed former phenocrysts.

Under the microscope, a power of at least 50 diameters, with good resolution is required for the correct determination of the dissociated

Scales of Palagonite in the Cave Sand of 'Jambuvanti Bhoira.'

particles, which vary in sizes from even less than $\frac{1}{500}$ to a little over $\frac{1}{100}$ inch. These in order of their abundance, consist :—(*i*).—Of principally angular but sometimes partially rounded fragments of colourless quartz, averaging about $\frac{1}{200}$ to $\frac{1}{300}$ inch across. (*ii*).—Large and somewhat rounded, yellowish-brown to brown scales of an amorphous semi-transparent material, measuring approximately $\frac{1}{100}$ inch, and frequently less, across. These are evidently comparable to the altered volcanic glasses called 'palagonite' which RUTLEY notes,* "results from the action of heated water or steam upon flows of lava, which affects the decomposition of many of the constituent minerals, and especially causes the peroxidation of any protoxide of iron compounds which the rock contains." It is just possible that the original rock consisted largely of a cryptocrystalline or undifferentiated vitreous ground-mass ; and it is doubtless these scales which glisten in hand-specimens and were mistaken for gold by native prospectors. (*iii*).—Small oblong forms of greyish to colourless crystals, about $\frac{1}{200}$ inch or so in length and showing traces of twinning, indicate the former presence of sanidine. (*iv*).—Splintery fragments of green augite, fairly fresh, but few and far between. measure on an average $\frac{1}{300}$ inch in length and less in breadth. (*v*).—Specks and granules of opaque black magnetite that have survived epigene reactions. No trace of fragments of micropegmatite, as such can be detected ; which points to the conclusion that any such structures if present, must have been completely disintegrated or that the original rock took the form of a spherulitic felsite.†

PHYLUM C.—VOLCANIC ROCKS.

EITHER COMMERCIALLY VALUABLE or of scientific interest, the rocks of this series that are worthy of determinations may be naturally

Volcanic Rocks of Porbandar State :—Bedded-lavas, Rhyolites and Basic Dyke-rocks.

classified in accordance with their origin, geological age and modes of occurrence, into three well-marked groups ; namely ;—(*i*).—The Bedded-lavas of Cretaceo-Eocene. (*ii*).—Light Lavas, Acid Volcanics or Rhyolites of probably Early Eocene. (*iii*).—Dark, Basic Dyke-Rocks, of date subsequent to the eruption of the Rhyolites.

* 'The Study of Rocks', London, 1879, p. 272.

† *Cf. ut supra*, pp. 99-103 ; Figs. 5 and 35-40.

Group I.—Bedded Lavas of the Deccan-Trap Period.

Bedded-lavas of the Deccan-Trap Period.

SUFFICIENT INFORMATION has already been afforded concerning the general mode of occurrence, geological structure, and localities in Porbandar State, whence large supplies of economic examples or noteworthy specimens, belonging to this group of rocks, can be obtained, both in the pages of this summary and those of the preceding narrative reports.* It would therefore be quite superfluous to render an abstract of observations made in the field; but as distinctly desirable, on the other hand, that a record of laboratory determinations should be given forthwith, as follows:—

Hypocrystalline Olivine-Basalt, Compact Zone of Bedded-lava

REGD. NO. 223.—Occurring exposed as a hilly-mound, $2\frac{3}{8}$ miles NE. of the town of Morwára, in a practically fresh condition, this typical sample of a 'Hypocrystalline Olivine-Basalt', manifestly represents the denuded middle or compact zone of a lava-flow, the upper vesicular or amygdaloidal portion of which has entirely vanished. The rock is exceedingly tough and strong, and only less durable than granophyre for road-metalling and the making of paving-setts, curbs and copings for which it is admirably adapted.

The Special uses of Basalts.

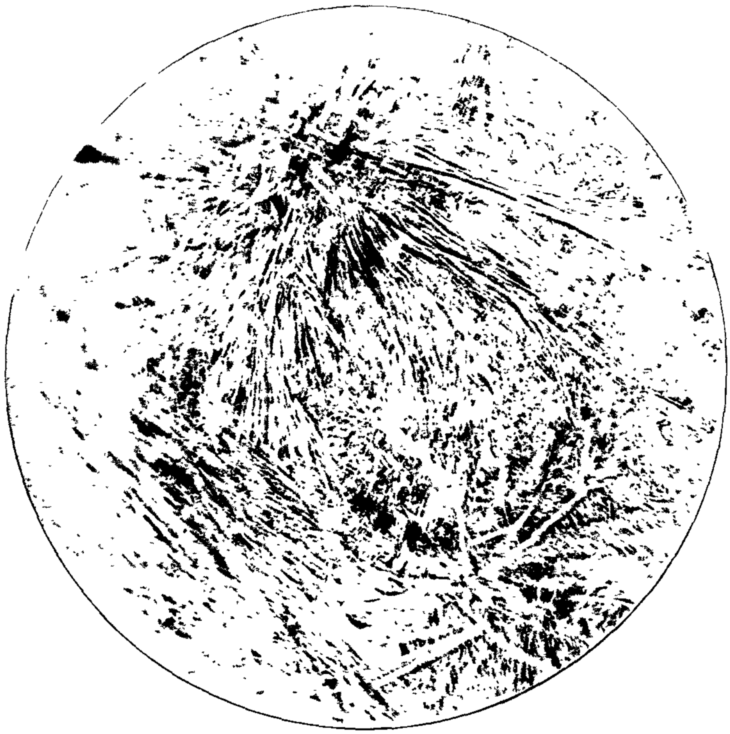
Hand-specimens show a fresh black clean-fractured surface liberally studded with minute glistening ruby-red crystals and a few glassy porphyritic patches, which, upon examination with a pocket magnifier or coddington lens, turn out to be large crystals of olivine and aggregates of colourless felspar. Although much used as building-blocks for dwelling-houses and the piers of bridges, the basalts as a rule are not to be preferred for such purposes, where the much stronger and far more durable granophyres are available, on account of the comparative rapidity with which they succumb to atmospheric influences. Indeed, for architectural elevations of any kind they are of less value than good limestone such as the miliolites; but for the macadamising of roadways, they are vastly superior to any kind of calcareous rock and second only to micro-granites and granophyres.

'Hypocrystalline' Texture and Intersertal' structure.

Determinations made with the microscope show the rock to be of 'hypocrystalline' texture, inasmuch as it displays a small amount of residual unindividualised glass, which is sometimes 'intersertal' in situation and either colourless or of a faint brownish hue. Fig. 46, Plate

* Consult 'Table of Contents' and 'General Index' to this volume.

PLATE L.



Regd. No. 190.—Fig. 52.—Black Obsidian.

Apophysis of Dyke, 350 yards WNW. of Nagka.

Resolved by WATSON AND SONS' 1 *inch Objective,* 0·21 *Numerical Aperture.*

Amplified 30 Diameters.

The field-of-view shows a colourless glassy matrix, closely crowded with elongated spicules of a neutral tint, apparently radiating from separate centres, presumably nucleated. The occasional black specks represent small crystals of magnetite. Under higher powers,—from 50 to 100 diameters the spicules may be seen to frequently show secondary branches at nearly right angles, and many of the larger ones appear to be hollow, and of the nature of skeleton crystallites, as they extinguish in all positions between crossed nicols. Judging from advanced phases of development the spicules are probably incipient forms of pyroxene.

XLIV, conveys a correct impression of the intimate structure of the stone, which is there seen to be composed mainly of a ground-mass studded with large porphyritic crystals of plagioclase felspar and olivine ; but there are no phenocrysts of augite.

The 'Glomero-porphyritic' structure of Professor Judd.

When rotated between crossed nicols, the colourless phenocrysts of felspar, exhibit albite lamellation and give extinction angles indicating that they belong to the variety called medium labradorite. They also show a tendency to aggregate into groups, (F. Fig. 46, Plate XLIII), styled the 'glomero-porphyritic' structure by PROFESSOR J. W. JUDD.* These phenocrysts exhibit an elongated habit, and individually measure as much as $\frac{1}{12}$ by $\frac{1}{15}$ inch, in thin sections.

Other phenocrysts, more plentifully distributed than those of felspar are represented by idiomorphic, usually six-sided sections of olivine, (O. Fig. 46, Plate XLIII), so rich in iron, that their margins and cleavage and other cracks are deeply stained to a bright brownish-red colour, apparent as glistening ruby-red crystals when viewed by the naked eye in freshly fractured hand-specimens. The kernels of the olivine phenocrysts are colourless and present shagreened surfaces by reason of their high refractive index ;—1·68. They generally contain inclosures of minute octahedra and grains of magnetite, and sometimes show light-brown internal patches with delicate closely parallel cleavages like those of mica ; but, being non-pleochroic, do not correspond with the Californian mineral described by LAWSON under the name of 'iddingsite.'† In size, large phenocrysts attain to the dimensions of $\frac{1}{15} \times \frac{1}{20}$ inch in sections.

The ground-mass contains, in order of abundance, the following constituents :—(*i*).—Colourless laths of medium to acid labradorite, the majority of which show multiple twinning and range in length from $\frac{1}{100}$ to $\frac{1}{50}$ inch or even less. They frequently exhibit a tendency to fluxional arrangement around the phenocrysts. (*ii*).—Minute grains mainly of irregular shapes, but sometimes assuming tabular idiomorphic forms of a pale greenish-brown augite, varying from $\frac{1}{400}$ to $\frac{1}{200}$ inch. (*iii*).—Small crystals and irregular grains of a second generation of olivine, deeply margined, and sometimes entirely obscured by red iron-oxide ; from $\frac{1}{150}$ to $\frac{1}{100}$ inch in dimensions. (*iv*).—Opaque black aggregated

* *Q. J. G. S.*, London, 1886, xlii, p. 71 ; pl. VII, fig. 3.

† *Bull. Geol. Dept.*, University, California, 1893, i, pp. 29-46 ; pl. IV.

crystals of magnetite, $\frac{1}{150}$ to $\frac{1}{100}$ inch across; and minute octahedra and specks measuring $\frac{1}{500}$ to $\frac{1}{700}$ inch. Sometimes the aggregated crystals of magnetite show traces of hexagonal outlines, and a superficial greyish-black colour when examined under reflected light, which leads to the belief that they represent intergrowths of magnetic and titaniferous iron-ores, or titanomagnetite. (*v*).—Interstitial, sometimes intersertal patches of colourless to faint brown residual isotropic glass, are sparingly present; but though not devitrified, show inclusions of excessively minute refringent microlites between crossed nicols.

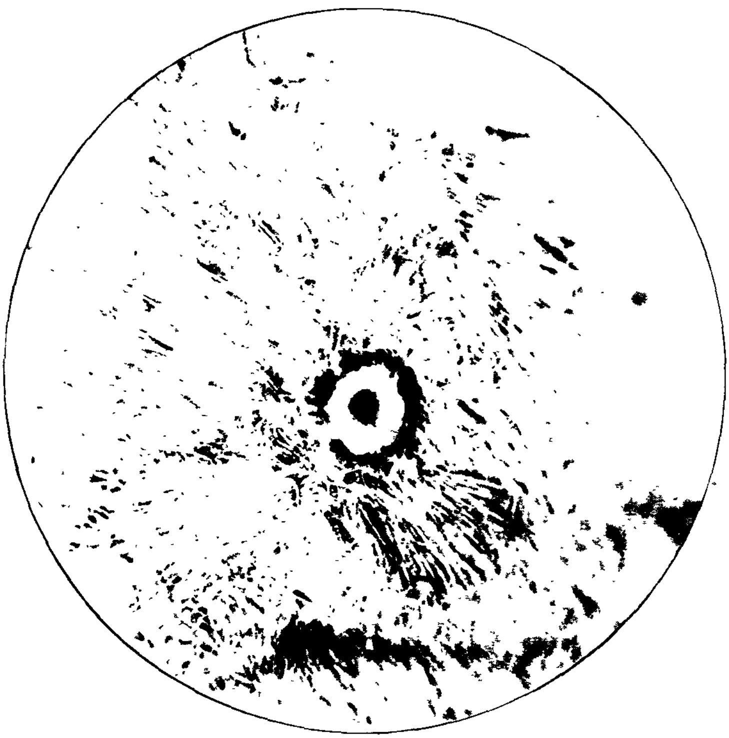
Amygdaloidal Basalt Typical of the Upper Zone of Bedded-lavas.

REGD. NO. 233.—Forming an irregularly-shaped eminence, $\frac{1}{2}$ mile in diameter, located by the roadside $1\frac{1}{2}$ miles WNW. of Morwára, determinations show this rock to be, the denuded remains of the upper zone of a lava-flow, and may be correctly called an 'Amygdaloidal Basalt.' The rock represents the lower portion of the amygdaloidal or vesicular zone of the bed of lava, inasmuch as its amygdales assume large spherical and smaller irregular contours, constituted by cores of fibrous zeolites, with occasional separations of chalcedonic silica. Many of the smaller amygdales,—$\frac{1}{50}$ inch, or less,—are enveloped in narrow shells of greenish silicide of iron; but the larger ones,—$\frac{1}{8}$ inch or so, in diameter, show narrow, crenulated rims of cloudy silica.

A peculiarity about this rock is, that while portions of the mass show ordinary columnar jointing, certain parts develop a closely reticular structure, dividing it into small polyhedra, which, by subsequent shrinkage, give rise to diminutive spheroids, which weather out at the surface into balls, each about the size of a school-boy's marble.

There does not appear to be any development, as usual, of phenocrysts in this specimen, which is very finely and uniformly textured and consists essentially of :—(*i*).—Small colourless laths, simply twinned, of acid labradorite or andesine, $\frac{1}{200}$ to $\frac{1}{150}$ inch in length. (*ii*). Grains of pale-brown augite, $\frac{1}{400}$ inch, or so, across. (*iii*).—Opaque-black crystals and grains of magnetite measuring from $\frac{1}{600}$ to $\frac{1}{300}$ inch. (*iv*).—A trifle of clear, but sometimes devitrified, brownish interstitial isotropic glass. (*v*).—The amygdales already noted, which are mainly composed of fibrous radiating aggregates of hydrous silicates of alumina,—probably of natrolite or mesolite.

Plate LI



Regd. No. 190.—Fig. 53.—Black Obsidian.

Apophysis of Dyke, 350 yards WNW. of Nagka.

Resolved by Watson and Sons' $\frac{1}{2}$ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

From another portion of the same thin section as that from which Fig. 52 was taken; showing, towards the centre of the field of view, the formation of an incipient spherulite. The spherulites, which are sporadically distributed, sometimes show traces of crystalline structure at their cores; occasionally of pale yellow epidote. In this instance the core is colourless and surrounded by an amorphous dark-brown zone, which in its turn is enveloped by a colourless glassy 'court of crystallisation.' The spicules of pyroxene are also surrounded by a small proportion of colourless, isotropic glass.

REGD. NO. 542.—Illustrated by Fig. 47, Plate XLV and Fig. 48, Plate XLVI.—This remarkable specimen may be accurately described as an 'Altered Amygdaloidal Basalt,' the alteration having been effected by thermal metamorphism. The rock was taken from a new well-shaft, where it occurs at a depth of 10 feet from the surface, and is overlaid by a deposit of basement beds of miliolite-limestone, 1½ miles NE. by NNE. of the picturesque village of Asiápát in the Barda Group of hills.

Altered Amygdaloidal Basalt, resulting through Thermal Metamorphism.

Although at a considerable distance from the base of the hills, and therefore not to be cited as an example of contact metamorphism, this rock, which belongs to the series of previously formed bedded-lavas in this locality, must have been profoundly affected by the injection of the vast hypabyssal dyke-rocks now denuded to form the mountain-massive ; for it bears many pronounced indications of alteration, when examined under the microscope.

The rock is very finely textured ; and, at first sight, does not show any differentiation into phenocrysts and a ground-mass ; but, by careful illumination under low magnifying powers, faint traces of porphyritic crystals in aggregates, may be just barely discerned, especially between crossed nicols. The remainder of the field of view, with the exception of the spaces occupied by the comparatively large amygdales, is constituted by a ground-mass essentially similar in details to that of Registered No. 543, presently to be described.

Bearing in mind the vicissitudes to which the material has been subjected, namely, to thermal metamorphism, followed by severe denudation and subsequent infiltrations of carbonated waters heavily charged with lime from the later deposits of miliolite, it is not surprising to find that the original amygdales, presumably zeolitiferous, should exhibit complicated changes. Some of the smaller amygdales develop shells of densely crowded ultramicroscopic particles and are filled with a pale sea-green substance resembling chlorite, but non-pleochroic, and exhibiting feebly illuminated radiating groups of fibres between crossed nicols, suggestive of serpentine. Others are filled with colourless plates of calcite, showing rhombohedral cleavage-traces, and iridescent greens and pinks of a high order ; and these are sometimes crowded with pale-yellow, non-pleochroic, monoclinic laths and irregular grains of what corresponds optically with epidote.

Lastly, there are still more curious complications in the altered structure of these amygdales, which are shown by the central portion of Fig. 47, Plate XLV, and in greater detail by Fig. 48, Plate XLVI. This large amygdale, which is manifestly the result of the coalescence of two former vesicles, measures about $\frac{1}{8}$ inch in length, by from $\frac{1}{12}$ to $\frac{1}{20}$ inch in varying breadth. It is constituted by an outer narrow light and a wider dark border of ultramicroscopic grey matter, inclosing a zone of aggregated microlitic grains of opaque black magnetite, deficient towards the smaller end of the amygdale. Within this there comes an incomplete band of a light grey apparently amorphous matter which seems, however, to be in direct continuity with a somewhat similar sub-central patch; but this patch, between crossed nicols, displays a division into mosaics giving the optical reactions of chalcedonic silica; while imbedded therein, there appear many monoclinic pale-yellow laths of evidently epidote. An intermediate area is filled with a pale sea-green, non-pleochroic substance, which shows edgings of radiating fibrils, of possibly serpentine, between crossed nicols.

Complicated Alterations within Amygdales of Basalt

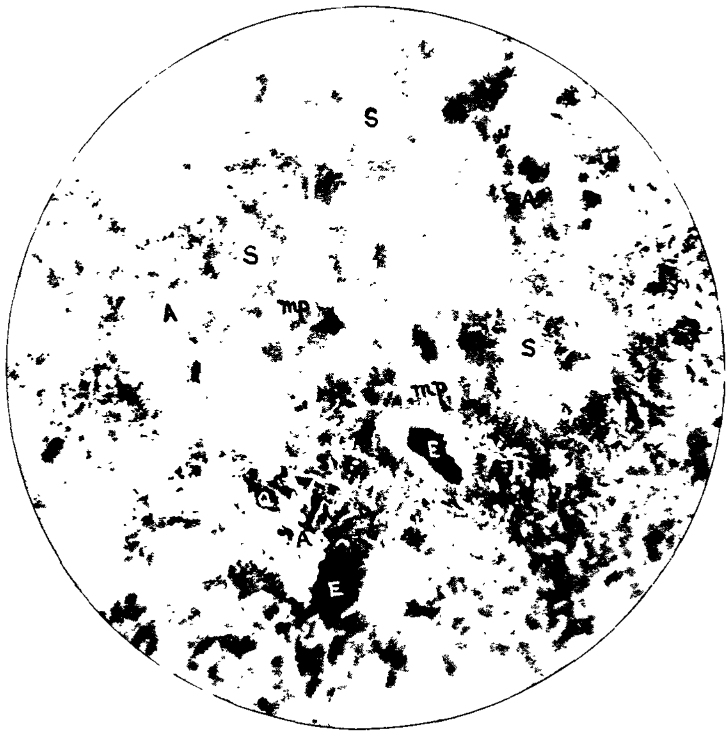
REGD. NO. 543.—Fig. 49, Plate XLVII, is a photomicrograph taken from a thin section of the same lava-flow as No. 542, but from below the depth of 10 feet, where the amygdaloidal zone, just commences to pass gradually into the middle or compact layer of the lava-bed. It will be noticed in the centre of the figure that an amygdale still persists; but a little lower down, the compact zone grows quite free from vesicles of any kind, and presents throughout, a structure precisely like that shown surrounding the amygdale in Fig. 48.

Altered Porphyritic Basalt, from the Compact-zone of Bedded-lava subjected to Thermal Metamorphism.

To realise the general structure of the stone, only a low magnifying power, will be found sufficient;—as shown by Fig. 48, where the field of view displays with great clearness the marked distinction between phenocrysts and ground-mass. It will be noticed, in the picture that the phenocrysts, which in this instance consist entirely of large colourless crystals of elongated habit, have a tendency to collect into groups;—the *glomero-porphyritic* structure of PROFESSOR JUDD. Between crossed nicols the triclinic crystals of felspar give, when rotated, extinction angles averaging 32°, and are therefore of the variety called medium labradorite.

Good Example of the 'Glomero-porphyritic' Structure of Professor Judd.

PLATE LII.



Regd. No. 186.—Fig. 54.—Hypocrystalline Rhyolite.

Centre of 20 ft.-high Dyke, [illegible] mile SW. of Nagka.

Resolved by WATSON AND SONS' $\frac{1}{2}$ *inch Objective,* 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

S.—Incipient spherulites, showing traces of radiating fibrous structure.—**mp.**—Crystals of felspar intergrown with quartz in form of excessively fine micropegmatite, which can just barely be discerned with this power. **Q.**—Subordinate mosaics of clear interstitial quartz. **A.**—Decayed elongated rods of pyroxene. The crystals and granules of opaque black magnetite observed elsewhere, have been oxidised into rust coloured specks and patches.

The ground-mass shows a plentiful crop of a second generation of microlitic laths, which give an average extinction angle of 23°, and are therefore of the nature of acid labradorite verging upon andesine. The interspaces left by this fine meshwork of felspar laths are crowded with diminutive granules of colourless augite (diopside) associated with a fairly equal proportion of minute grains and aggregated grains of opaque black magnetite ; while there also occurs a small residuum of greyish isotropic glass.

Peculiarities obtain in the sporadic occurrence of small, imperfectly developed endomorphs of diopside in some of the felspar phenocrysts, in the presence of a few sub-spherical amygdales and in the formation of a kind of cloudy grey reticulum, which pervades the ground-mass irregularly, and owes its singular appearance to closely packed granules of augite, unaccompanied by particles of magnetite. This segregation of augite granules can just barely be resolved by the use of a one inch objective with an amplification of at least 50 diameters.

The central amygdale depicted in Fig. 49, Plate XLVI, points to the circumstance that the specimen was taken from the *upper* part of the central zone of the lava-bed ; by reason of the fact that vesicles or steam pores, are confined to the superficial portions of each lava-flow, and gradually decrease towards the middle of the mass. The sub-spherical amygdale in Fig. 49, shows a greyish granular border of almost utramicroscopic particles of augite (diopside), passing inwardly into a zone of pale yellow granules of, probably, epidote. Next comes a light-grey crenulated zone of minute granules of, presumably, more augite ; while the core of the structure is occupied by closely crowded minute particles of opaque black magnetite. The rock may therefore be styled an 'Altered Porphyritic Basalt,' and dates back to the earlier days of fissure eruptions of the Deccan-Trap Period.

Fissile Amygdaloidal Basalt.

REGD. NO. 306.—Fig. 50, Plate XLVIII, by reason of its peculiar mode of occurrence,* may be described as a 'Fissile Amygdaloidal Basalt.' How the fissility,-which lies parallel to the bedding, originated, must, for the present remain an enigma ; but, when examined with a low magnifying power, thin sections show an alternately coarse and fine arrangement of the mineral units.

* *Vide ut supra*, 'Narrative Report,' p cix.

No marked distinction between phenocrysts and ground-mass is observable in the photomicrograph, Fig. 50; but, in other parts of the same preparation, a few larger colourless laths of triclinic felspar,—medium labradorite,—may be detected, and perhaps, dignified by the name of phenocrysts of actual *intratelluric* consolidation. These larger laths, which are few and far between, measure from $\frac{1}{15}$ to $\frac{1}{25}$ inch in length; whereas, the microlitic laths, also of colourless laboradorite, assume slender forms which rarely exceed $\frac{1}{150}$ inch in length, but are much oftener only $\frac{1}{400}$ inch long, and doubtless represent PROFESSOR ROSENBUSCH'S *effusive* period of consolidation.

Professor Rosenbusch's 'Intratelluric' and 'Effusive' Periods of Consolidation.

Wedged in between the meshes of the felspar laths, are irregular patches of almost ultramicroscopic granules of brownish augite. These aggregates, sometimes measure as much as $\frac{1}{150}$ inch across; while the individual granules average about $\frac{1}{1000}$ inch in diameter. Opaque black magnetite in minute octahedra and larger compound crystals,—from $\frac{1}{400}$ to $\frac{1}{200}$ inch across, are comparatively conspicuous in this fine texture, and are freely disseminated throughout the field of view.

Amygdales occur only occasionally, and are usually discoid, and occupy positions more or less parallel with the planes of fissility. One of these is shown in vertical section at A, Fig. 50, Plate XLVIII; and exhibits a very finely fibrous structure, with a dark brownish crenulated border of inwardly radiating, and a lighter core of greyish fibrils, feebly refringent and otherwise indicative of its zeolitic character.

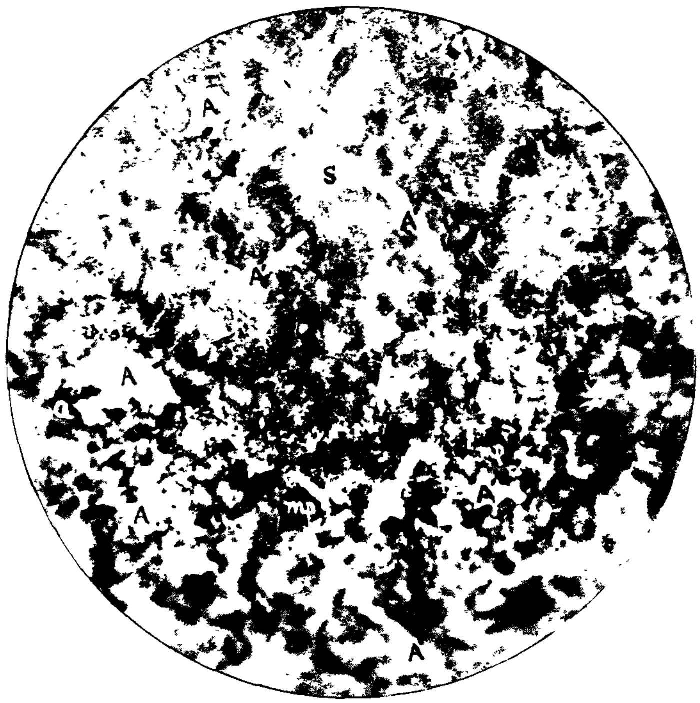
REGD. NO. 256.—Fig. 51, Plate XLIX.—Without observations in the field it would be difficult if not impossible, from hand specimens or even from thin sections to indicate the affinities and true nature of this singular rock, the mode of occurrence and locality of which have already been recorded.* It forms an exceedingly thick stratum of strangely altered bedded-lava, underlying deposits of consolidated shell-sand,—raised beach,—of the Dwárka Group, by the side of the sea-shore on the SW. side of Bhávpura, and may be considered to furnish an example of chemical metamorphism, due to the percolation of both salt and fresh water through the overlying calcareo-siliceous beds, to react upon the lava below.

Highly Altered Compact Basalt:—the Result of Chemical Metamorphism.

Exposed at a depth of about 5 feet from the surface, by a recently sunk well-shaft, the stone exhibits all the characteristics of the compact

* *Vide ut supra*, 'Narrative Report.' pp xcvi, ci

PLATE LIII.



Regd. No. 180.—Fig. 55.—Micropegmatitic Rhyolite.

Centre of Dyke, Paria Dhar, ½ mile E. of Bawawao.

Resolved by WATSON AND SONS' ½ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

Practically a sub-holocrystalline texture, composed essentially of ;—**mp.**—Micropegmatitic crystals of felspar barely resolvable as such under this power. **Q.**—A very subordinate proportion of mosaics of clear interstitial quartz. **S.**—Incipient spherulites exhibiting radial fibrous structure. **A.**—Irregular plates of dusky brownish-green augite **A'.**—Dusky brownish green crystals of pyroxene of elongated habit. The opaque black crystals and granules of magnetite disseminated throughout the field, are too minute to be indicated by lettering.

or middle zone of a very thick bed of lava, the upper or amygdaloidal portion of which appears to have entirely succumbed to denuding agents. The subsequent deposition of Dwárka shell-sands, or arenaceous limestone upon this substratum, and the infiltration of carbonated salt and fresh waters through them into the underlying bedded-lava, has been effectual in converting the latter into a soft brown to bluish-green and ash coloured clay, with the exception of rows representing the nuclei of former spheroids. These nuclei are also changed to an ashy or bluish-green colour, but preserve their hardness sufficiently to enable thin sections to be readily prepared. The rock may therefore be correctly called a 'Highly Altered Compact Basalt.'

Excessively fine in texture, a magnifying power of at least 50 diameters will be found necessary to resolve the mineral units of the rock. There are many sporadic irregularly shaped elongated spaces from $\frac{1}{100}$ to $\frac{1}{30}$ inch long, filled with a feebly refringent, granular, green alteration product, studding the field of view. These are bounded by a brighter green, almost isotropic crenulated borders; and the whole structure is surrounded by more or less colourless unindividualised glass, resembling 'courts of crystallisation.' In consideration of the fact, that the altered nuclei of spheroids, from a sample of which No. 256 was sliced, unquestionably belong to the compact zone of the lava-bed, these green bodies, can scarcely be regarded as altered amygdales; but are more likely to be the chemically metamorphosed representatives or pseudomorphs of former felspar phenocrysts. If so, the bulk of the rock consists of a delicate andesitoid ground-mass, which, from the examination of many thin sections, does not appear to show signs of change, and is constituted by:—(*i*).—Colourless, microlitic laths of triclinic felspar,—basic labradorite,—measuring from $\frac{1}{400}$ to $\frac{1}{200}$ inch in length. (*ii*).—Irregular aggregates of greyish to colourless granules of augite, the individual granules of which average less than $\frac{1}{1000}$ inch across. (*iii*).—Diminutive octahedra and granules of opaque black magnetite, about $\frac{1}{1000}$ inch in diameter. (*v*).—A small proportion of colourless, residual, isotropic glass, filling up interspaces.

Fissile Amygdaloidal Olivine-Basalt, with Discoidal Amygdales.

REGD. NO. 235.—Approaching Wadála, about 100 yards or so on the E. side of the town, there is an eminence of large blocks of a dark black stone, which exhibits the unusual peculiarity of flow-structure by the presence, at irregular intervals, of discoidal zeolitiferous amygdales, measuring from the fraction of an

inch to over an inch in diameter, but seldom exceeding a quarter of an inch in thickness. The stone is exceedingly tough and compactly textured, but so splintery as to be of little value, save for road-metal. It is here specially noticed on account of its uncommon fissility, which points to the consolidation at the earth's surface of a particularly mobile, and therefore decidedly basic lava flow.

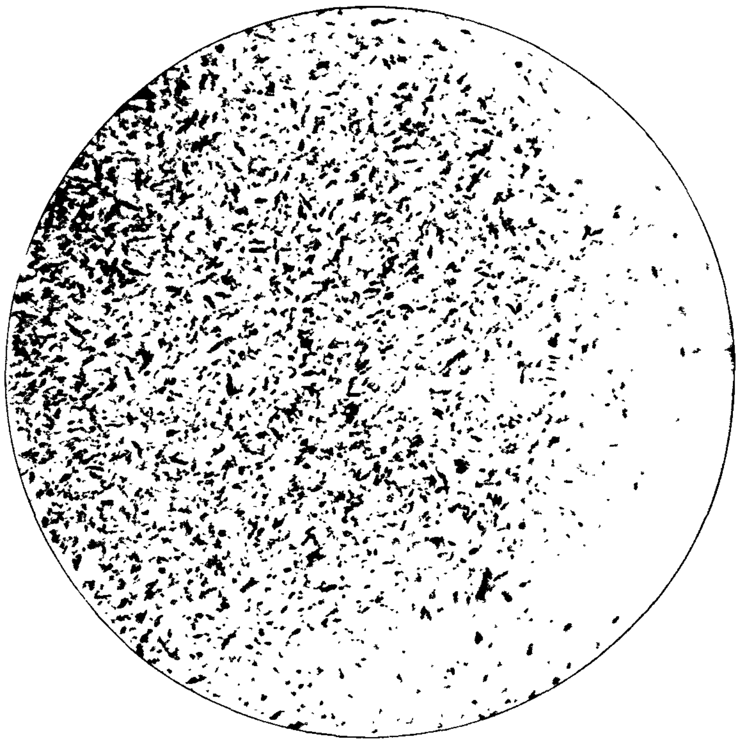
Optically examined, thin sections show a few elongated laths of colourless triclinic felspar, seldom exceeding $\frac{1}{25}$ by $\frac{1}{100}$ inch in dimensions, and giving the extinction angles of basic labradorite and bytowrite. Numerous microlitic laths of a less basic labradorite, from $\frac{1}{200}$ to $\frac{1}{150}$ inch in length, and trending more or less in one direction, constitute the dominant feature of the ground-mass, the interspaces of which are filled by aggregated granules of greyish augite, each about $\frac{1}{1000}$ inch across, and minute octahedra and compound crystals of opaque black magnetite, $\frac{1}{1000}$ to $\frac{1}{400}$ inch in size, in almost equal abundance. A very small proportion of residual glass can barely be identified with high magnifying powers brought to bear upon extra thin parts of the preparation ; while there also occur a good many ill-defined, dusky-greenish crystals, about $\frac{1}{200}$ by $\frac{1}{300}$ in average size, of olivine. The rock may therefore now be correctly registered as a 'Fissile Amygdaloidal Olivine-Basalt.'

Laterised Amygdaloidal Olivine-Basalt of the Contact-zone, showing Stem-like Amygdales.

REGD. NO. 232.—This specimen is of comparatively rare occurrence in Porbandar State, although plentifully in evidence elsewhere in the Province of Káthiáwár. It represents the lowermost or contact-zone of a lava-flow, which originally happened to pass over the cold surface of a previously consolidated bed, in the presence, in this particular instance, of a superabundance of moisture. The primary effect of this passage of molten material over a moist chilled surface has been to cause jets of steam to be forced vertically upward into the consolidating lava-flow, with the result that elongated and frequently branched cylindrical vesicles are formed, which ultimately become filled with secondary products and thereby give rise to a series of sub-parallel, vertically disposed, stem-like bodies homologous with the amygdales of the upper or superficial zone of the lava-flow.

Contact metamorphism in this case, accompanied by the presence of an excess of moisture, has caused a reaction analogous in all respects to incipient laterisation, so that the substance of the stone has been

PLATE LIV.



Regd. No. 154.—Fig. 56.—Fine-textured, Densely-Black Basalt.

Half-a-mile NW. by WNW. of Bakharla.

Resolved by WATSON AND SONS' 1 *inch Objective*, 0·21 *Numerical Aperture.*

Amplified 30 Diameters.

An excessively fine textured field of view is here shown in which the dominant mineral consists of microscopic laths of colourless triclinic felspar,—medium labradorite, all belonging to the effusive period of consolidation; for, there are no phenocrysts. Wedged in between these variously orientated laths, are aggregates of very small granules of pale brownish-grey augite; while equally diminutive crystals and irregular grains of opaque black magnetite are plentifully scattered throughout the field-of-view. By careful examination a small proportion of colourless to pale greyish-brown isotropic, residual glass may be detected filling interspaces.

altered to a brick-red colour ; while the cylindrical, sub-vertically disposed vesicles, filled with white zeolites, bordered by rims of bright green silicide of iron, give to the rock quite an ornamental appearance. This does not presuppose, however, that the material can be utilised in any way on a commercial scale, simply because these lower or contact zones scarcely ever attain to more than a few inches in thickness, and are moreover prone to part into small pieces upon being handled.

Nature of the Stem-like Amygdales

The stem-like amygdales, as they are usually called, are generally branched, and but a few inches in length at the utmost. They give circular, ovoid and irregular transverse sections ; and, in this instance, show zeolitic aggregates of a milk-white colour in bulk by reflected, but colourless and pellucid when viewed by transmitted light. Under the microscope, the contents of the amygdales appear in form of a mosaic of allotriomorphic, colourless crystals of fibrous structure, and giving straight extinction when rotated between crossed nicols. They are therefore of the variety *natrolite* ;—a hydrated silicate of sodium and aluminium, which belongs to the orthorhombic system ; but shows no visible bisectrix or optic axes in a cleavage flake.

The substance of the rock itself has manifestly undergone changes due to contact metamorphism and the presence of much moisture, for it may be seen to consist :—(i).—Of minute laths of colourless triclinic felspar—medium labradorite, $\frac{3}{200}$ inch in mean length. (ii).—Sporadic crystals of olivine, frequently $\frac{1}{10}$ inch long, heavily indued with red ferric hydrate. (iii).—An interstitial brick-red, nearly opaque substance, of the nature of hydrous silicate of alumina and also perhaps of a simple hydrate of alumina, deeply stained with ferric hydrate. This, in effect, is identical with the natural process, known as *laterisation*, with special reference to volcanic rocks, and has clearly been brought about at the expense of the augite and magnetite of the compact, finely-textured basalt that would otherwise have been formed.

Occurring several feet from the surface of a newly sunk well-shaft, $\frac{3}{4}$ mile W. by WNW. of the town of Morwára,* this lowermost zone of the lava-flow, although of frequent occurrence, is only rarely met with in a condition coherent enough to admit of being sliced for microscopical examination, except by excavation ; for when laid bare by subaerial denudation or the erosion of rivers and streams, it very rapidly disin-

* *Cf. ut supra*, 'Narrative Report,' p. xc.

tegrates and crumbles to pieces upon being handled. This specimen may therefore now be named a 'Laterised Amygdaloidal Olivine-Basalt of the Contact-zone.'

Opaque Tachylyte Encrusting a Lava-flow near Morana.

REGD. NO. 198.—'Opaque Black Tachylyte'.—In his admirably arranged handbook DR. HARKER, the present President of the Geological Society notes* :—" The name *tachylyte* is commonly employed to cover the glassy representatives of both the basalts and the pyroxene-andesites, besides other basic glasses richer in alkalies;" and again, † "*tachylyte*, is of very limited distribution, being found commonly as a very thin crust on some lava-flows or a narrow selvage to basalt-dykes. It consists of a brown or yellow glass densely charged with a separation of magnetite. This is sometimes in globulites disseminated through the glass so as to render it almost opaque, or collected in cloudy patches (cumulites); at other times it forms trichites or crystallites of minute size. Perlitic structure is less common than in the obsidians. Interesting spherulitic structures are met with in some examples. When distinct phenocrysts occur abundantly in the glassy ground-mass, we have what is called the 'vitrophyric' structures. The basic glass is subject to alteration, probably involving, as a rule; hydration and other chemical changes, but the resulting substance, known as *palagonite*, is still an isotropic glass; —yellow, brown or sometimes green in sections."

Palagonite or Altered Volcanic-glass.

The sample under consideration was detected forming a thin crust, scarcely exceeding one inch, adherent to a fairly fresh zone of compact bedded-lava at its contact with an underlying bed of decayed amygdaloidal lava,‡ situated in the dry channel of the river Wartu, about 350 yards N. of the village of Moràna. The material was found, to resist being reduced into sections thin enough for microscopic examination, and remained opaque even at the thinnest edges, so that it could only be viewed by reflected light, which revealed faint traces of a polygonal mosaic, studded with a few small circular sections of a white to yellowish semi-transparent, feebly refringent substance, probably representing altered spherulites, and patches of whitish ill-defined forms, which are likely to be the relics of former crystals.

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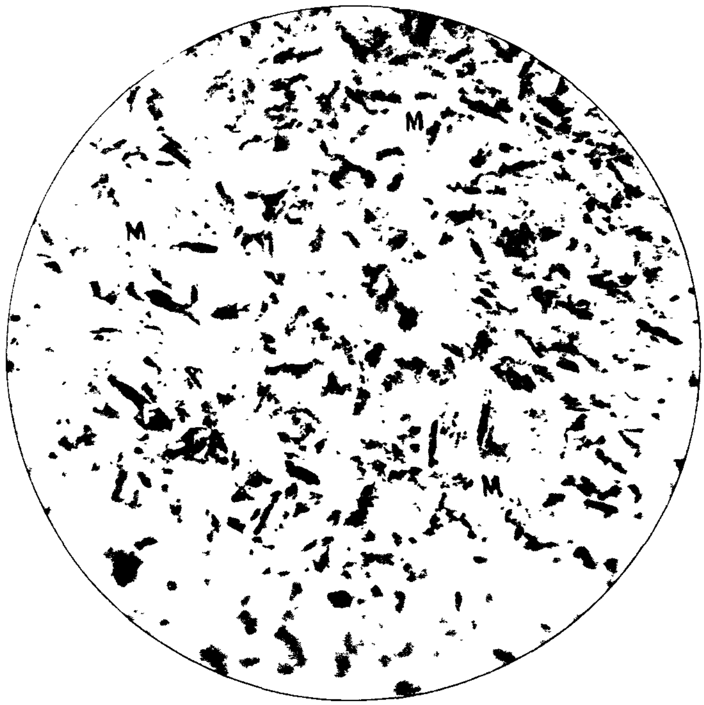
* 'Petrology for Students,' Fourth Edition, Revised, Cambridge, 1908, p. 210.

† *Op. cit*, p. 207.

‡ *Cf. ut supra*, 'Narrative Report'. p. lxxvii.

PLATE LV.



Regd. No. 213.—Fig. 57.—Cleaved Compact Basalt.

Well-shaft, 500 yards E. of Sisli.

Resolved by WATSON AND SONS' ½ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

Of somewhat coarser texture than the specimen No. 154, but of essentially similar structure. **F.**—Minute laths of colourless triclinic felspar,—medium labradorite. **A.**—Aggregated granules of pale brownish-grey augite, wedged in between the felspars. **M.**—Well-defined small crystals and irregular grains of opaque black magnetite, plentifully represented throughout the field of view. All the mineral units are in a perfectly fresh, *i.e.*, unaltered condition. A residuum of isotropic colourless to pale brownish glass can be detected in interstitial positions.

In other parts of the Province, many good examples of tachylytes have been met with, both at the contact planes of lava-flows, and as selvages to small dykes of basalt ;* and doubtless, diligent searching among the bedded-lavas and dykes of the northern-districts of Porbandar State, would be rewarded by the discovery of their presence in more typical development.

Indurated Laterite and Bole.

Other phenomena in connection with the contact-zone of lava flows, although they have not been located in Porbandar State, are of frequent occurrence among the bedded-lavas of the Province;—notably by the formation of thin brick-red bands of indurated material, like laterite, and of thicker beds of bole†;—both of which are manifestly produced by the passage of a lava-flow over beds of previously consolidated lavas, the surfaces of which have been decomposed into more or less soil. This basaltic soil, saturated with meteoric water and then baked to redness by the heat of overflowing molten material, was first observed and described in connection with the lava beds of Mount Etna nearly sixty years ago.‡

Origin and True Nature of the Laterites of Porbandar State.

This naturally leads once more to the somewhat perplexing subject of the origin and true nature of the many varieties of laterite found in Porbandar State ,of which detailed records have already been given.§ Thin sections under the microscope do not reveal much more information than what can be gathered by observation in the field, except by demonstrating the precise nature of organic limestones, which by their presence in proximity to laterite formations, have become so heavily impregnated with ferric hydrate as to be mistaken for the laterite itself. These, in the form of a shelly conglomerate, probably belonging to the base of the Dwárka Group of beds, and of what appears to be the remains of a deposit of miliolite overlying the shelly conglomerate, are registered as Nos. 246 and 247 on the list of the State Geological Collection, and are prominently exposed by the roadside, 2 miles SSW. of Wadála, *en route* to Tukra.

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* ADYE, 'Memoir on the Economic Geology of Navánagar State,' Bombay, 1914, pp. 98-100 ; Plates XV-XVI.

† ADYE, *Op. cit.*, pp. 55, 87, 88.

‡ SIR CHARLES LYELL, *Philosophical Transactions of the Royal Society*, London 1858, p. 711.

§ *Vide ut supra*. pp. 25-32 ; and especially p. 41.

REGD. NO. 253.—Approaching the NE. side of the village of Tukra, the laterite, available in large solid blocks, presents quite a unique and ornamental appearance, manifestly due to the filling up of its vesicles, with infiltrations of limonitic-limestone derived from Gáj beds which were formerly deposited upon the submerged laterite in Miocene times.

'Tukralite' or Laterite with Infiltrations of Gaj Limonitic-limestone.

When cut and polished, the surface of this stone presents a mottled appearance of deep brick-red patches, bound together by pale to bright yellow areas of interstitial matter. Sections cannot be ground thin enough to enable the latter to be resolved, under high magnifying powers, into infinitesimally minute granules of amorphous limonitic lime, plates of calcite and small crystals of dolomite, so characteristic of the microscopic structure of the Gáj limestone deposits ;* but, by reflected light, the yellow areas may be clearly seen to be of the character of infiltrated matter deposited as concretions around the patches of brick-red laterite and collecting in the interspaces, into diminutive concretionary spheres. This specimen, by reason of its ornamental character and probable commercial value, has been given the specific name of 'Tukralite.'

REGD. NO. 278.—It is well-known that when laterite disintegrates and is drifted down to lower levels, the clastic particles, have a strong tendency to cohere into solid structures resembling a conglomerate, which moreover catch up and incorporate adventitious particles of sandy quartz and other minerals to form the so-called *low-level* laterites.† The specimen under consideration, however, does not, as at first sight, appear to conform to this category ; for, upon careful examination of thin sections under the microscope, they show evidences of an originally laterised basalt, having undergone subsequent internal re-arrangements of its component parts, *e.g.* :—The segregation of interstitial hæmatite and of a general diffusion of limonite ; while the vacuoles are filled with a whitish clay which is liable to lose its silica through the percolation of meteoric waters, and to accumulate into patches of aluminium hydrate, commercially known under the name of *bauxite*, as one of the best ores of aluminium.

Low-level Laterites.

Bauxite or Aluminium-ore.

In No. 278, the aluminium hydrate segregates into concretionary

* *Cf. postea*, p. 143.

† *Cf.* 'Manual of the Geology of India,' 2nd Edition, Calcutta, 1893, p. 273.

Fig. 58.—Pindaralite, from the Original Site.

Quarter-mile S. of Pindara Village.

Amplified 35 Diameters.

O.—Pseudomorphs, in mosaics, of colourless recrystallised calcite, of various organic remains, proper to an estuarine-marine habit, under tranquil conditions of sedimentation. **L.**—Particles of laterite decomposed into opaque black, deep brown and reddish patches of oxides and hydrates of iron. **C.**—Microgranular matrix of particles of amorphous calcite stained yellow with limonite. Under higher powers the matrix may be seen to consist of irregular granules and clear crystalline mosaics of calcite, with a few minute rhombohedra of dolomite.

Fig. 59.—Upper Semi-Circle.—Orbitoidal-limestone.

Two and a half miles S. by SSE. of Pindara.

Matrix Amplified 240 Diameters.

From a camera-lucida sketch by E. HOWARD ADYE, F. G. S., etc.

D.—Micro-rhombohedra of colourless, zoned, nucleated and sometimes skeleton crystals of dolomite, more or less deeply etched with ruddy-brown hydrate of iron. **Y.**—Irregularly shaped granules of amorphous,—precipitated—calcite, stained yellow with limonite. **C.**—Mosaic of colourless secondary calcite.

Fig. 59.—Lower Semi-Circle.—Limonitic-limestone.

Bed of Karipat Vokala, 2 miles NE. of Bhogat.

Matrix Amplified 150 Diameters.

This specimen is crowded with the remains of micro-organisms. **F.**—Tests of *Foraminifera*, (*Rotalidæ*), with loculi, **C′.**, filled with recrystallised calcite. **C.**—Mosaic of colourless interstitial secondary calcite. **Y.**—Patches of granules of amorphous calcite stained yellow with hydrate of iron. **L.**—Rounded and irregular patches of opaque black or ruddy-brown decomposed laterite.

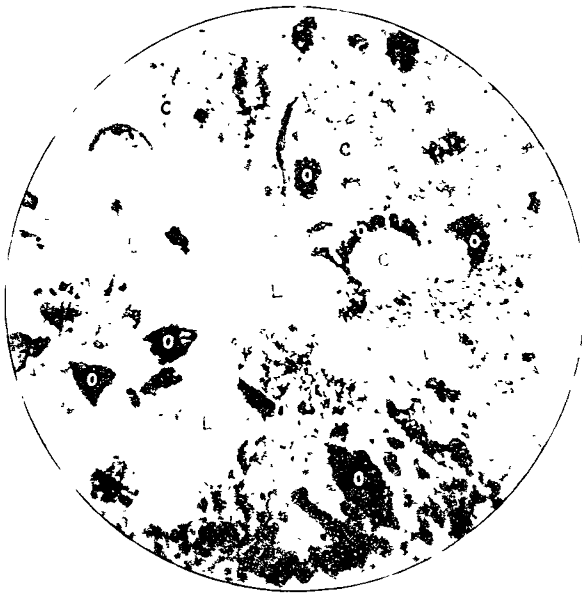

Fig. 58.

Fig. 59.

spheres of practically isotropic matter of a whitish colour, and gives to the rock-mass its character as a 'Pisolitic Laterite.' These spheres, frequently as large as peas, usually vary in size from about $\frac{1}{10}$ to $\frac{1}{8}$ inch in diameter, and are freely associated, in the vacuolated mass, with other irregularly shaped particles many of which, by their interference tints, point to their nature as silicates of alumina; while a few show signs of basaltic structure by the presence of refringent colourless laths of presumably triclinic felspar, so much altered, perhaps by pseudomorphosis, that they do not give extinctions between crossed nicols.

Pisolitic Laterite.

When miliolites or other organic limestones are deposited in the neighbourhood of lateritic formations, and are subjected to infiltrations through the drift from the laterite, they generally become so thoroughly impregnated as to closely resemble the laterite itself in hand specimens. Under the microscope, however, their true nature becomes instantly apparent; for the organic structure of the stone,—its fragments of shells, foraminiferal tests, echinoid spines, etc., and binding mosaic of re-crystallised calcite all remain intact; but the ferric hydrate from the laterite will be found to have penetrated and been deposited, as opaque brick-red matter, into the smallest interstices, invading even the loculi of the *Foraminifera* and the formerly empty spaces of the calcified areolar tissues of echinoderms.

Group II.—Light Lavas, Acid-Volcanics or Rhyolites.

EXHAUSTIVE notes on the rhyolites of Porbandar State;—their geological age, modes of occurrence, varieties and uses, have already been given in these pages; * but special reference may once more be directed to the differences that subsist between these acid volcanic or eruptive rocks and the *felsites* of hypabyssal origin,† both of which have about the same silica percentages. It therefore now remains to place on record, a few descriptions of typical varieties of the group.

Light-lavas, Acid-Volcanics or Rhyolites.

REGD. No. 190.—The mode of occurrence of this, the only glassy type of rhyolite,—called 'Obsidian' after OBSIDIUS, who discovered it,—as the apophysis of a branched dyke, is clearly shown, *in situ*, by the eroded exposure of a *nala*, near the village of Nágka, reproduced in these pages from a photograph, as Fig. 11, Plate

Coal-black Obsidian.

* *Vide ut supra*, pp. 32—38.

† *Ibidem*, p. 37.

IX. The vein,—for it is little else,—of coal-black volcanic-glass, is pervaded by countless cracks, which render it difficult to obtain even small slices sound enough to survive the process of grinding upon a lapidory machine; but by dint of perseverance, these were secured, and thin sections prepared for microscopic examination, from which the photomicrographs Fig. 52, Plate L and Fig. 53, Plate LI, were taken. The intimate structure of the stone,—which is of no commercial importance, but of some scientific interest,—is sufficiently explained below the figures on the abovenoted plates.

Brown-grey Rhyolite.

REGD. NO. 184.—An advance in structure upon the obsidian is shown by this specimen of a typical brown-grey rhyolite, which has evidently acquired its colour through prolonged sunbaking. The stone occurs exposed in form of a broad low dyke, ⅝ mile W. by WSW. of Nágka, and exhibits strongly marked traces of flow-structure towards its edges even to the naked-eye, by the rough pseudo-lamination of its surface.

Crystallites:—Longulites and Margarites.

Under a magnifying power of about 50 diameters, the field-of-view shows a cryptocrystalline matrix, crowded with crystallites and microlites, more or less sub-parallel and trending in one direction,—the direction of flow of the formerly molten lava. The crystallites are in the form of *longulites*, occasionally resolvable into *margarites*; while the microlites appear to be more highly differentiated units of the same sort, but giving indications of their nature as some variety of pyroxene, accompanied by separations of granules of magnetite, which are also freely disseminated throughout the structure.

Between crossed nicols, the cryptocrystalline matrix reveals its compound character, as an intimate intergrowth of felspar and quartz; and also shows sundry patches of mosaics of clear, colourless crystals of secondary quartz.

Special uses of Rhyolites.

Towards the centre of the dyke, the flow-structure is not quite so apparent to the naked eye. The stone shows a columnar structure with spheroidal shrinkages, and being easily available in sound blocks of large sizes, capable of being readily tooled with native implements, might be profitably utilised, as in the United

PLATE LVII.

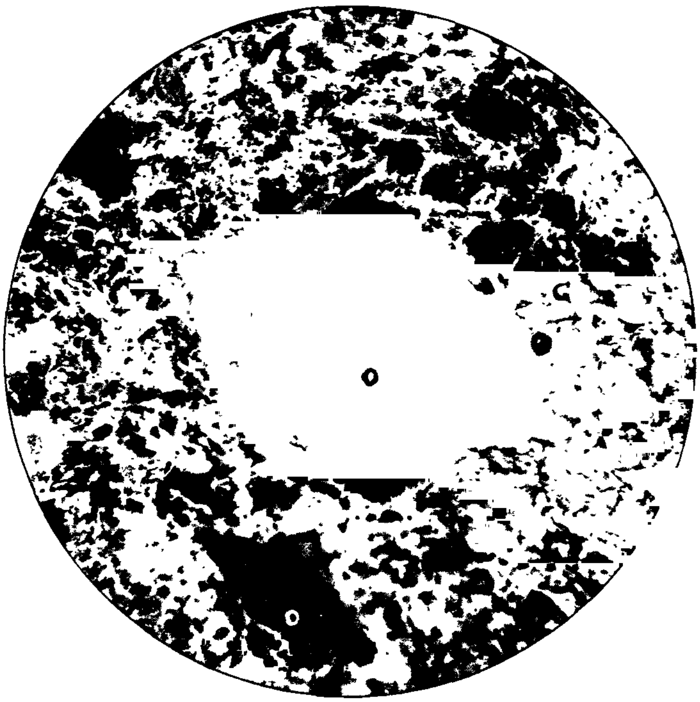

Fig. 60.—Orbitoidal Limonitic-Limestone.

Same Site as Specimen shown by Fig. 59, Lower Semi-Circle.

Amplified 25 Diameters.

Deep-yellow, compact but coarsely textured Gáj limonitic-limestone, crowded with the calcareous tests of:—**O.**—*Orbitoides*, sp., which exhibit a large central chamber, surrounded by sub-circular, median and superficial chamberlets. **L.**—Fragments of nullipores or calcareous *Algæ*,-*Lithothamnion*. **G.**—Matrix of the stone constituted by the fragmentary remains of a vast variety of marine organisms, cemented together by colourless mosaics of secondary calcite, amorphous calcite in granules stained yellow with hydrate of iron, and decomposing particles of laterite as shown in greater detail by fig. 59, Plate LVI, Lower Semi-circle. **T.**—*Textularia*.

States of America,* especially as the light and dark browns, fawn-colours and greys of the rhyolites would afford a novel and pleasing contrast to the sombre hues of the basalts and other basic volcanic rocks now so extensively employed; while the wastage together with the abundant angular shingle commonly found on the slopes of the dykes could be broken to gauge for road-metal, superior in durability to the sedimentary rubble now so largely used in the State.

Hypocrystalline Rhyolite.

REGD. NO. 186.—This specimen, which was taken from the central portion of a high dyke, the edges of which displayed marked flow-structure, identical in character with that described immediately above, may be correctly named a 'Hypocrystalline Rhyolite', inasmuch as the mass shows a strong tendency to the formation of crystals when thin sections are examined under the microscope with transmitted light, as shown by Fig. 54, Plate LII, which is emphasised between crossed nicols.

The stone, which occurs in large columnar blocks, is sunbaked at the surface to a purplish-brown hue; and, to the naked-eye presents a compact, uniformly fine texture; but there can be no doubt, that when blasted, the perfectly fresh material as elsewhere,† would assume a good grey tone, and being easily available in large quantities, could be profitably utilized for building purposes.

Spherulitic Rhyolite.

Incipient crystallisation is indicated by frequent spherulitic forms; while, especially with polarised light, many outlines of felspar crystals may be vaguely identified;—showing under powers of 100 diameters or more an almost ultramicroscopic intergrowth with quartz, identical with an excessively fine micropegmatite. Free quartz is also sporadically represented by secondary mosaics occupying interspaces, while slender elongated crystals and spicules of pyroxene and numerous grains of magnetite are scattered throughout the field of view. The rock, as might be expected from the above optical determinations, is considerably tougher and stronger than those portions which exhibit flow-structure and are of altogether cryptocrystalline structure.

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* *Vide ut supra*, p. 36.

† *Postea*, p. 136.

Micropegmatitic Rhyolite.

REGD. NO. 180.—By reason of its dominant constituent in the form of a sub-holocrystalline structure of micropegmatitic felspar crystals, this specimen, from the compact central part of the large dyke called Páriá Dhár,* may be correctly styled a 'Micropegmatitic Rhyolite.' The exposed stone does not happen, in this instance, to have been much affected by atmospheric reactions, for it maintains its fresh grey colour, being merely tinged at places with purplish hues due to sunbaking.

The micropegmatitic character of its small felspar crystals, which are probably of the nature of sanidine, can only just barely be discerned under a magnifying power of 50 diameters; but with powers of from 100 diameters and more, becomes plainly manifest. These crystals, however, although forming the main bulk of the stone, are occasionally replaced by incipient spherulites, with radiating fibres;—as shown by the reproduction of a photomicrograph, S., Fig. 55, Plate LIII.

In this section, moreover, the ferromagnesian constituent is clearly represented by pyroxenes, in the form of abundant, irregularly-shaped, tabular, dusky-green crystals of augite, and slender, smaller crystals of elongated habit of the same mineral; while the opaque black magnetite, occurs only in infinitesimally small specks and granules, frequently decayed to a brown colour, and scattered throughout the field of view. Free quartz is very sparingly represented, filling small interstitial spaces in the form of clear, colourless mosaics, at irregular intervals.

Group III.—Dark, Basic-Volcanics or Dyke-Rocks.

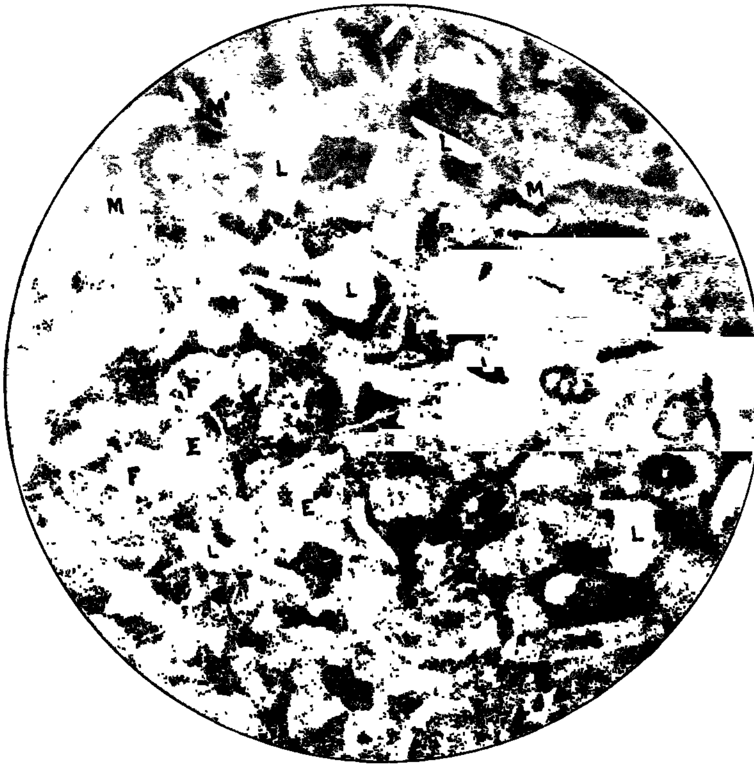
Dark, Basic-Volcanics or Dyke-rocks.

FOLLOWING closely upon the eruption and consolidation of the dykes and lava-flows of rhyolites, and probably heralding the cessation of volcanic activity in the Province of Káthiáwár, during the Lower Eocene age, there are many gigantic basic dykes which traverse the countryside, more or less latitudinally for several miles in unbroken continuity;† but it is doubtful whether more than a very few of the long low and often underground basic dykes of Porbandar State belong to this category. Among these, the Kunwádar-Májiwána-

* *Cf. ut supra*, 'Narrative Report,' pp. lxvii-lxx.

† ADYE, 'Memoir on the Economic Geology of Navánagar State,' Bombay, 1914, p. 77. *et sequentes*.

PLATE LVIII.



Regd. No. 148.—Fig. 61.—Consolidated Shell-sand.

Light Variety, E. slope of Bhado Dhar.

Resolved by WATSON AND SONS' 1 *inch Objective*, 0·21 *Numerical Aperture.*

Amplified 30 Diameters.

C.—Plate of colourless calcite forming a unit of the secondary mosaic. **C'.**—Calcite plate showing twin lamellæ. **L.**—Irregular patches of translucent brown; probably ferric hydrate derived from the decomposition of clastic fragments of laterite. **F.**—Recalcified tests of *Foraminifera*,—*Peneroplis* sp.? **F'.**—Recalcified outline of test of foraminifer,—*Rotalia* sp.?—**M.**—Opaque black iron-ore, probably separated from laterite. **E.**—Calcified areolar tissue of echinoids. **E'.**—Echinoid tissue converted into oxide of iron. **M'.**—Acicular flake of colourless muscovite. **Q.**—Small angular grains of quartz. **X.**—Centre of field-of-view, shown more highly magnified by Fig. 62.

Sisli dyke,* may be specially noted as likely to have been extruded from a focus in the Barda Group of hills. There are many subsidiary dykes however, of dense-black basalt, which run for comparatively short distances, and evidently belong to a period of greater antiquity ;—the age of fissure eruptions which resulted in the formation of the bedded-lavas.

Texture and Structure of Basic Dyke-rocks.

These dyke-rocks, of whatever age, are of excessively fine texture, and generally so closely jointed as to yield small polyhedra, with individual spheroidal shrinkages, which can be readily broken into an angular shingle suitable for road-metal, at small cost, and only inferior in durability to fresh granophyres of the highest grades. Microscopically examined they present the intimate structure pictured by Fig. 56, Plate LIV and Fig. 57, Plate LV.

Densely Black Basalt of Bakharla.

REGD. NO. 154.—An excessively fine-textured, densely black basalt, which outcrops in form of a 20 feet wide dyke cutting through the bedded-lavas, $\frac{1}{2}$ mile NW. by WNW. of the village of Bákharla. Its locality and mode of occurrence have already been registered†, so that it now only remains to give a description of its microscopic structure, in support of the claim that the stone is admirably adapted for use as a superior and long-lasting road-metal suitable for macadamising heavy-traffic highways.

Of uniformly fine texture throughout, and without phenocrysts, the mineral units, all in a perfectly fresh condition comprise :—(i).—Variously orientated micro-laths of colourless triclinic felspar,—medium labradorite,—simply twinned, by reason of their minute dimensions which rarely exceed $\frac{1}{300}$ inch in length. (ii).—Wedged in closely between the felspar laths, are aggregates of brownish-grey granules of augite ;—infinitesimal in size. (iii).—Liberally scattered throughout the field-of-view, come diminutive crystals and grains of opaque black magnetite, seldom more than $\frac{1}{500}$ inch across. (iv).—With high powers and extra thin sections a very little residual isotropic glass can be detected.

* *Vide ut supra,* 'Narrative Report,' pp. lxxiii, lxxv, lxxxii.

† Ut *supra,* 'Narrative Report,' pp. lv, lvii.

REGD. NO. 213.—Forming part of the comparatively narrow but far-stretching dyke of compact black basalt, which can be traced intermittently aboveground in Porbandar State from Kunwádar *viá* Májiwána to the boundary beyond Sisli,—a total distance of about $7\frac{1}{2}$ miles,* this specimen was taken from a section of the dyke, exposed by a well-shaft, about 500 yards E. of Sisli, where the rock had manifestly undergone such intense lateral pressure, and was forced past so many obstacles, as to become closely cleaved and contorted. It was therefore expected that the minute structure of the mass would be modified; but upon the examination of thin sections under the microscope, no signs of alteration could be detected.

The Kunwadar-Majiwana-Sisli Dyke of Densely-black Basalt.

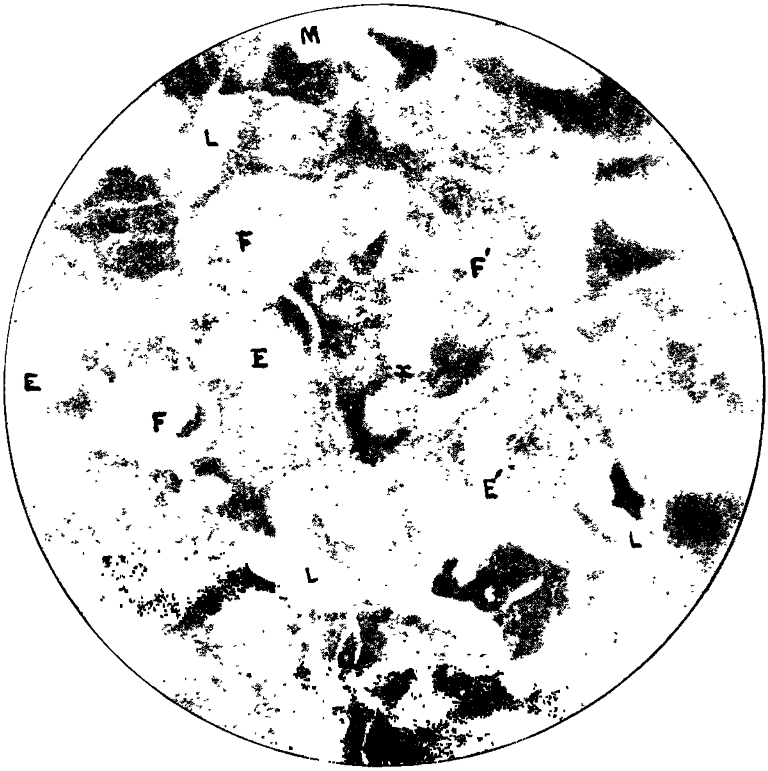
Figure 57, Plate LV, shows the reproduction from a photomicrograph of the rock, which, from its mode of occurrence, has been named a 'Cleaved Compact Basalt.' Of practically dense and uniform texture throughout, the absence of phenocrysts points not so much to the circumstance of its consolidation entirely during the 'effusive period,' as to its rapid cooling near the surface of the earth;—for there are instances where the central portion of a large dyke exhibits a distinction into phenocrysts and ground-mass,—the 'intratelluric' and 'effusive' phenomena of ROSENBUSCH,—while the rapidly chilled edges or contact parietes of the mass show no sign of two generations of any of the mineral units.

Cleaved Compact Basalt of Dyke near Sisli.

It will be noticed, by comparison of Figs. 56 and 57, that the latter is somewhat more coarsely textured than the former; but that their mineral constituents are essentially similar and in an equally fresh or unaltered condition. In the sample under consideration, the colourless triclinic felspar laths,—medium labradorite,—occasionally show polysynthetic twinning and measure from $\frac{1}{200}$ to $\frac{1}{150}$ inch in length. The aggregated granules of brownish-grey augite are very clearly defined, but excessively minute,—$\frac{1}{1000}$ to $\frac{1}{700}$ inch. The magnetite, in opaque black octahedra and irregular grains and compound crystals, range in sizes from mere specks up to about $\frac{1}{400}$ inch or a trifle more across; while the colourless or pale brownish-grey interstitial, isotropic, residual glass, is clearly discernible. The rock may thus be recommended as admirably adapted for the making and maintenance of rural highways.

* *Vide ut supra.* 'Narrative Report,' pp. lxxiii, lxxv, lxxxii.

PLATE LIX.



Regd. No. 148.—Fig. 62.—Consolidated Shell-sand.

Light Variety, E. slope of Bhado Dhar.

Resolved by WATSON & SONS' ½ *inch Objective,* 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

C.—Plates of calcite forming units of the secondary mosaic. **L.**—Irregular patches of translucent brown; probably ferric hydrate derived from the decomposition of clastic fragments of laterite. **F.**—Recalcified test of foraminifer,—*Peneroplis* sp. ? **F.**—Recalcified outline of test of foraminifer,—*Rotalia* sp. ? **E.** Calcified areolar-tissues of echinoids, in **E′**, replaced by opaque black iron-ore. **M.**—Opaque black iron-ore probably separated from laterite. **Q.**—Small angular fragment of quartz. **X.**—Centre of field-of-view.

PHYLUM D.—SEDIMENTARY ROCKS.

Sedimentary Rocks of Porbandar State.

SEDIMENTARY ROCKS, or rocks derived from the deposition of matter held in mechanical suspension or chemical solution in water, must be clearly distinguished from kindred formations that have originated subaerially ;—for both are represented among the economic stones of Porbandar State.

Accepted Classification of Sedimentary Rocks.

For the sake of convenience, petrographers have classified sedimentary or aqueous rocks into four groups ; which, however, are not strictly distinct, but gradually pass from one into the other :—(i).—Sandy, arenaceous, or usually coarsely grained detrital deposits. (ii).—Clayey, argillaceous or more finely textured detrital deposits. (iii).—Calcareous rocks, chiefly composed of carbonate of lime. (iv).—Pyroclastic rocks, or rocks of fragmental igneous origin.

Clastic Units and Allothigenous and Authigenous Constituents of Sedimentary Rocks.

With the exception of certain calcareous and siliceous deposits such as travertine, stalagmites and stalactites and siliceous sinters, etc. sedimentary rocks are essentially fragmental or built up of *clastic* or derived units from the wearing-down of previously formed rocks, and these are known as their *allothigenous* constituents. Subsequent to the accumulation of these units derived from a distance,—whether they are of the nature of organic remains or not,—the clastic grains are usually more or less cemented together by secondary matter, either recrystallised or in an amorphous condition, derived from finely divided material deposited along with the grains, or from infiltrations, or dissolved emanations from the grains themselves. These secondary materials are called the *authigenous* constituents of the stone-structures.

Merchantable Stones of Sedimentary Origin found in Porbandar State.

In Porbandar State, the merchantable stones of sedimentary origin are mainly of the nature of marine deposits, and these are principally of a mixed character, *i.e.*, partly calcareous and partly arenaceous, with clear evidences of pyroclastic additions ; while the argillaceous group is only poorly represented by river mudstones, conglomerates of river-terraces and a few lacustrine mudstones,—notably in the bed of the Khambála Talav, and the potter's clays found periodically deposited by small streams and from ponds and dammed-up reservoirs.

In dealing with types of economic stones of sedimentary origin, it would be both more convenient and useful to follow on the lines of the Geological Record or succession of rocks, than to attempt to classify the numerous examples according to their chemical composition, or physical attributes. The groups of this phylum, will accordingly be considered as follows :—(i).—The Gáj Limonitic-limestone or Miocene Beds. (ii).—The Dwárka Beds ;—probably Post-Miocene to Lower Pleistocene.

Group I.—The Gaj Group of Beds.

The Gaj Group of Beds in Porbandar State.

UPON THE CESSATION of volcanic activity in the Province in early Eocene times, there are evidences to show that a period of violent denudation must have supervened ; especially throughout the regions of the southern, south-western and western coastal borderlands of the peninsula. It was doubtless at this juncture that extremes of solar heat alternating with such downpours of rain as had never before nor since been experienced hereabouts, combined to cause those superficial metasomatic changes in the then exposed bedded-lavas of the coastal borderland, which resulted in the formation of the laterite ridges and areas ;*—now such a conspicuous feature of the countryside.

By the time that a gradual subsidence of the coastal borderland took place in the Miocene Period, (equivalent with the Gáj Group of Sind†), the deposits of detrital matter, mainly of a calcareous character would naturally become more or less heavily mixed with particles of laterite and indued with hydrate of iron ;—hence the prevailing yellow-colour of the Gáj Group of limonitic-limestones and conglomerates.

Basement Beds of the Gaj Group in Porbandar State.

The basement beds of the Gáj Group, being constituted mainly by littoral and occasionally by deeper sea deposits, present a series of both compact and loosely textured conglomerates and occasional coral reefs, which are fairly well represented in Porbandar State. The conglomerates are, as a rule, exceptionally rich in fossil remains ; and although of no commercial value in the stone markets, are nevertheless well worthy of the attention of palæontologists and collectors of museum specimens, which sometimes realise ' fancy prices.'

* *Cf. ut supra*, p. 41.

† So-called after the beds exposed by the banks of the Gáj river in Sind. See *Memoirs, Geol. Survey, India*, 1879, xvii, p. 53.

PLATE LX

Regd. No. 148.—Fig. 63.—Consolidated Shell-sand.

Dark Variety, E. slope of Bhado Dhar.

Resolved by WATSON & SONS' 1 *inch Objective,* 0·21 *Numerical Aperture.*

Amplified 30 Diameters.

S.—Elongated rounded chips of shells of *Mollusca,* showing traces of histological structure. **M'.**—Elongated rounded chips of shells of *Mollusca,* thoroughly recalcified. **M.**—Cementing mosaic of colourless secondary calcite. **F.**—Complete test, recalcified of a foraminifer,—*Rotalia.* **E.**—Calcified areolar tissues of echinoids in rounded patches, indued with deep brown to black, probably derived from decomposed laterite. **C.**—Interstitial patches of colourless calcite showing cleavages and twin lamellæ. **Q.**—Grains, angular, but sometimes slightly rounded, of clear colourless quartz.

Good Localities for Gaj Fossils in Porbandar State.

Good localities for Gáj fossils, have been carefully recorded as follows :—

REGD. NO. 104.—Underlying the finely-textured Gáj limonitic limestone of the pindáralite-type, at a depth of about 20 feet from the surface of a new well-shaft, on the N. side of the Dwárkadish Gardens, within the Bokhira limit near Porbandar City. The rubbly stone piled up in heaps by the well-sides, when weathered, can be seen to be closely crowded with both casts and true fossils of a very varied description, chiefly of the shells of *Mollusca*, echinoderm spines and tests, fragments of *Polyzoa*, corals and a host of other marine Miocene organic remains,

Microscopic Fossil-remains found in the Gaj beds.

Under the microscope, especially in the more finely-textured strata overlying the conglomerate, many well-preserved tests of *Foraminifera* of littoral and deeper-sea habit may be identified ;—chiefly species of *Orbitoides*, *Miliolina* and *Textularia* ; with numerous fragments of calcareous *Algæ*,—*Lithothamnion*,—popularly known as nullipores.*

Fossiliferous Gaj Limestone near Visawara.

REGD. NO. 280.—From a well-shaft situated $1\frac{1}{8}$ miles NW. of Visáwára, and outcropping for several yards around, large numbers of fossil casts of the shells of molluscs are weathered out periodically and may be found thickly strewed upon the surface of the ground ; while by diligent searching fragments of echinoderms and corals may also be identified, clearly belonging to the basement beds of the Gáj limonitic-limestone.†

Gaj Fossils near Sirinagar

REGD. NO. 323.—Immediately underlying, a thick bed of shelly flagstones, a rubbly deposit of Gáj limonitic-limestone, exposed by erosion, occurs towards the NW. edge of the *talav*, or dammed up stream reservoir, about 200 yards distant from the village of Sirinagar, from which many fossils were gathered, including the internal cast of a shell of *Strombus gigas*.‡

Gaj Fossils near Renawara.

REGD. NO. 349.—From an abandoned well-shaft, $\frac{1}{3}$ mile N. by NNE. of Renáwára, a very finely weathered-out museum specimen, crowded with well-preserved fossils and casts of marine Miocene *Mollusca* was secured ; and the neighbourhood appears to be prolific not only in fossiliferous rocks of the Gáj Group, but in the

* *Cf. ut. supra*, 'Narrative Report,' pp. xxxvi, xxxvii.

† *Ut supra*, 'Narrative Report,' p. civ

‡ *Cf. ut supra*, 'Narrative Report,' pp. cxvi, cxxi.

more finely textured beds of the Pindáralite-type which can be turned to profitable account as ornamental stones.*

Stylophora Coral-zone in the Gaj Limestone near Bharwara.

REGD. NO. 151.—A remarkable outcrop, eroded by the channel of the Álaswána Vokala, ¼ mile S. of Bhárwára, discloses the Gáj limonitic-limestone, densely crowded with the branched stalks of the madreporarian coral *Stylophora* † with a few single corals, occasional valves of *Venus cancellata* of the rotund variety and a specimen of *Turritella vittata.*‡

Megascopic Fossil-remains of Porbandar State named and classified.

In addition to the microscopic forms of life,—the fossil remains of which have not yet been thoroughly investigated,—the following well authenticated list of Tertiary (Miocene), fossils have already been discovered in the Gáj Group of beds of limonitic-limestones and conglomerates of Porbandar State :—

ALGÆ.—Fragments, usually rounded of various nullipores ;—*Lithothamnion.*

CŒLENTERATA.—Coralla and fragments of the madrepores :—*Cladocora* sp., *Pachyseris murchisoni*, *Stylophora* sp., and *Trochocyathus* sp.

MOLLUSCA.—Class LAMELLIBRANCHIATA.—Shells or casts of :—*Astarte hyderabadensis*, *Cardium triforme*, *Cucula trigonalis*, *Cyprina* sp. *Dosinia pseudoargus*, *Ostrea multicostata*, *Pecten bouei*, *Pecten favrei*, *Pectunculus pecten*, *Placuna* sp., *Pullastra virgata*, *Spondylus rouaulti*, *Tellina sub-donacialis*, *Venus non-scripta* and *Venus cancellata.* Class GASTROPODA.—*Cassis* sp., *Cerithium rude*, *Cypræa humerosa*, *Cypræa nasuta*, *Natica callosa*, *Natica* sp., *Phasianella oweni*, *Strombus gigas*, *Trochus cognatus*, *Trochus cumulans*, *Trochus loryi*, *Turritella subfasciata*, *Turritella angulata* and *Voluta edwardsi.* Class CEPHALOPODA.—Internal shell of *Sepia* sp., fragment of *Nautilus* sp.

POLYZOA.—Small fragments of the ectocysts of undetermined genera and species, observed in thin sections under the microscope.

ECHINODERMATA.—Entire tests, spines and fragments of calcified areolar tissues of:—*Breynia carinata* and *Brissopsis* sp., § *Cidaris depressa*

* *Cf. ut supra*, 'Narrative Report,' pp. cxxiv, cxxvi.

† *Cf. ut supra*, 'Narrative Report,' pp liv, lvii ; p. 62.

‡ FEDDEN, *Memoirs, Geol Survey, India*, Calcutta, 1884, Vol. xxi, Part 2, p. 46.

§ DUNCAN and SLADEN. *Palæontologia Indica*, Series xiv, Vol I, Part 4, pp. 80-91.

PLATE LXI.

Regd. No. 148.—Fig. 64.—Consolidated Shell-sand.

From another part of the same Preparation, shown by Fig. 63.

Resolved by WATSON & SONS' 1 *inch Objective*, 0·21 *Numerical Aperture*.

Amplified 30 Diameters.

S.—Elongated chips of shells of *Mollusca*, many of them rounded and showing traces of histological structure. **M'.**—Elongated chips of shells of *Mollusca*, thoroughly recalcified. **E.**—Calcified areolar tissues of echinoids, heavily impregnated with deep brown hydrate of iron probably derived from decomposed laterite. **E'.**—Traverse section of spine of an echinoid. **F.**—Chambers of a rotaliform foraminifer, filled with deep brown ferric hydrate from decayed laterite. **C.**—Colourless calcite showing cleavages and twin lamellæ. **M.**—Fine interstitial mosaic of colourless calcite. **Q.**—Quartz, colourless and partially rounded.

Cidaris granulata, Clypeaster depressus, Echinaster sp., *Euspatangu patellaris, Schizaster granti, Temnechinus affinis, Temnechinus costatus, Temnechinus rousseaui* and *Temnechinus tuberculosus.*

ARTHROPODA.—Fragments of the carapace and chela of a crab.

Pindaralite and Orbitoidal Limestones of the Gaj Group.

In illustration of the microscopic structure of the Gáj limonitic-limestones of Porbandar State, it may be noted that the conglomerates bearing the large recognisable fossils enumerated above, also hold many minute remains which cannot be seen by the naked-eye. These, however, are more abundantly represented in special interbedded zones, of finer texture, some of which are almost ultramicroscopic, save for the organic remains which they have preserved. Of such, the variety named 'Pindáralite'* by the writer, and the coarser stones, crowded with characteristic tests of *Foraminifera*, designated 'Orbitoidal-limestones,' claim prior attention in this place.

Pindáralite has a widespread distribution in Porbandar State, but its outcrops are not sufficiently well developed to yield large blocks of ornamental stone on a commercial scale. The principal localities for these have been registered under Nos, 103, 149, and 309†. From the occurrence underground of a tolerably thick bed of the stone, however, it is but reasonable to expect, that more or less deep-seated beds capable of yielding blocks of sufficiently large dimensions, and in quantities to meet all market demands, exist throughout the extensive area, in the neighbourhood and beneath the City of Porbandar itself, which is now covered deeply by the raised-beach,—Dwárka,—beds of consolidated shell-sands.

Microscopic Structure of Pindaralite.

The microscopic structure of Pindáralite, is best shown by samples from the original locality, ¼ mile S. of the village of Pindára in Návánagar State, here illustrated by Figs. 58 and 59, Plate LVI, with explanatory text. In somewhat coarser-textured samples, the matrix of the stone may be seen under varying powers of the microscope to be composed of the calcareous remains of several forms of plant

* ADYE, 'Memoir on the Economic Geology of Navánagar State,' Bombay, 1914. p. 177.

† *Vide ut supra*, 'Narrative Report,' pp. xxxvi, xxxvii, liii, lvii, cx and cxii ; also p. 16.

and animal life, peculiar to the littoral of the sea. These are chiefly present in a fragmentary condition, but many of them occasionally happen to be preserved in a fairly perfect state as shown by Fig. 60 Plate LVII.

Among the organisms so preserved, the occurrence of numerous examples of the delicately beautiful discoidal tests of the foraminifer *Orbitoides*, which belongs to the family *Nummulinidæ*, entitles the stone to be called an 'Orbitoidal Limonitic-limestone'; and, according to DR. G. J. HINDE, F.R.S.,* it includes the species *O. dispansa* and *O. ephippium*, which were discovered in the Gáj-limestones of Sind. Fragments of nullipores or calcareous *Algæ* of the genus *Lithothamnion* are also abundantly represented, together with entire tests of other *Foraminifera* , comminuted shells of molluscs, the spines and other calcified areolar tissues of echinoids, the ectocysts of *Polyzoa*, bits of corals, fragments of *Crustacea*, and adventitious detrital matter chiefly of the nature of detached pieces of decomposing laterite, all of which are closely cemented together by secondary calcite in colourless mosaics and diminutive irregular granules stained yellow with ferric hydrate.

Metasomatic changes in the Gaj Limestones

Metasomatic changes moreover, have evidently been active during and after sedimentation ; for, with magnifying powers of about 100 diameters or more, the cementing matrix may be seen to have developed microscopic rhombohedra of dolomite, sometimes in such abundance, that the rock can be said to have been *dolomitised*.

Dolomitisation.

Dolomitisation of the calcite in limestones consists essentially in the replacement of half of its lime by magnesia ; but that the resulting dolomite is not isomorphous with calcite is proved by their differences in specific gravity,—that of the former 2.872, being greater than that, 2.843, of an isomorphous admixture of calcite and magnesite in equal molecular proportions.† An appreciable contraction is thereby caused by the union of the two carbonates, which is often strikingly apparent in large masses of dolomite,—presumed to have previously existed as limestones,—by their cavernous, fissured structure.‡.

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* In a private communication from the late A. J. JUKES-BROWNE, F.R.S., January, 1912.

† *Cf.* SIR HENRY A. MIERS, 'Mineralogy,' London, 1902, pp. 241, 401, 402.

‡ SIR A. GEIKIE. 'Text-book of Geology', 4th Edition, London, 1903, p. 426.

PLATE LXII.

Regd. No. 429.—Fig. 65.—Consolidated Shell-sand.

100 yards WSW. of Tunkra, Along Bedding.

Resolved by WATSON & SONS' $1\frac{1}{2}$ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

S.—Elongated chips of lamellibranchiate shells, showing clear traces of histological structure. **G.**—Well-rounded clastic units of Gaj limonitic-limestone. **G'.**—Well-rounded clastic units from arenaceous beds of upper strata of Gaj limonitic-limestone. **F.**—Tests of *Foraminifera*, the upper complete one is rotaliform ;—*Rotalia* sp. **Q.**—Rounded grains of colourless quartz. **C.**—Subordinate mosaics of clear, colourless calcite. **C'.**—Matrix of colourless fibrous calcite. **E.**—Empty spaces.

Under the microscope, it is sometimes difficult to distinguish between calcite and dolomite ; but, as a rule, it may be noted that the cleavage traces of the former, coupled with its indications of twin lamellation, ought to suffice to separate it from the minute primary rhombohedra of dolomite, which moreover commonly show twinning by hemitropy about the vertical axis of symmetry ;—the two twinned rhombohedra interpenetrating.*

Lemberg's Microchemical Tests for Calcite, Dolomite and Brucite.

Much more delicate and satisfactory however, are the microchemical tests applied by J. LEMBERG,† to distinguish dolomite from calcite and from the brucite,—hydrate of magnesium,—contained in the 'predazzite' of the Tirol. These tests may be applied to either powders or thin sections under optical observation as follows :—(i).—Advantage is taken of the fact that calcite precipitates ferric hydrate from a solution of ferric chloride much more rapidly than does dolomite. LEMBERG, therefore, directs that one part of the crystallised chloride should be dissolved in ten parts of water and filtered. This filtrate should be allowed to react on the sample to be tested for a few seconds only (always less than one minute), and immediately decanted. Calcite becomes coated with a film of ferric hydrate ; while on dolomite the solution has but slight effect. By subsequent treatment with ammonium sulphide, the film of ferric hydrate is converted into black sulphide on calcite, but only shows a pale green on the grains of dolomite ; while brucite takes on a slightly stronger colour than the dolomite. If the three minerals are heated slightly after treatment with $(NH_4)_2S$, and AgNO solution, the brucite becomes black, the calcite turns brown, but the dolomite remains colourless. (ii).—Prepare a solution of four parts of aluminium chloride in sixty parts of distilled water, add six parts of logwood, and heat for twenty-five minutes with stirring. Treat samples with the solution for from five to ten minutes. Calcite will be stained violet, while dolomite and brucite remain but slightly affected.

REGD. No. 150.—Of more than usual interest by reason of

* DR. A. HARKER, 'Petrology for Students', 4th Edition, Cambridge, 1908, p. 271.

† *Zeits, d. d. deutsch. Geol Gesellsch.*, xxxix, 1887, p. 489 ; xl, 1888, p. 375; Abstracts in *Min-Mag.*, Vol. viii, 1889, p 166, and ADYE's 'Atlas of Microscopical Petrography,' London, 1906, p. 64.

its fresh cinnamon colour, sound and compact texture, and occurrence in blocks and slabs of large dimensions suitable for ornamental stone-work, this specimen being practically unique of its kind among the Gáj limonitic-limestones of the State, has,—in anticipation of its being sooner or later turned to commercial account,—been deemed worthy of the distinctive name *Bhárwáralite*, from its typical development, 1¼ miles SW. of the village of Bhárwára and about 6½ miles distant from the sea-shore.*

Bharwaralite:—New name for an Ornamental Variety of Gaj Limonitic-limestone.

Although comparable in essential respects with the Pindáralite described above†, the stone presents peculiarities in its intimate structure, which serve to separate it from other deposits of the Gáj group of beds, as hereunder detailed:—It resembles Pindáralite by being built up from the remains of a varied assortment of marine Miocene organisms, cemented together by secondary calcite, and heavily indued with the ferric hydrate stain of decomposed laterite;—but there the resemblance ends. Instead of well-preserved organic remains, the latter, including the minute tests of *Foraminifera*, are more or less shattered, but not beyond recognition; while small fragments of astræan and arborescent corallites predominate to indicate the existence of a fringing coral-reef. Many tests of *Foraminifera*, seldom entire, as already stated, come next in abundance, while spines and calcified tissues of echinoderms, the ectocysts of *Polyzoa*, and a few comminuted recalcified shells of molluscs and crustaceans are also represented. Nullipores occur but sparingly, and angular grains of quartz are rare. The whole of these are compactly entombed in a very strongly developed mosaic of secondary calcite, which is much obscured by the infinitesimally minute specks of decomposed laterite,—ferric hydrate,—which doubtless endows the rock-mass with its characteristic colour and comparatively hardness. Dolomite cannot be detected.

Microscopic structure of Bharwaralite.

On the 25th July, 1916, a special excursion was taken to Khari Khán near Khimeshwar Temple on the sea-shore near Kunchri, for the purpose of securing a picture of the excavations to show the formation of Recent sub-aerial accumulations beneath the sand-dunes there situated, and advantage was taken of the oppor-

Additions to the State Geological collection.

* *Vide ut supra*, 'Narrative Report', pp liii, lvii. also p. 42

† *Ut supra*, p. 143.

Plate LXIII.

Regd. No. 429.—Fig. 66.—Consolidated Shell-sand.

A Portion of Fig. 65, more highly Magnified. Along Bedding.

Resolved by Watson & Sons' $\frac{1}{2}$ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

F.—Part of the test of a rotaliform foraminifer,—*Rotalia* sp.—, showing, **I,** radiating interseptal canals, and chambers only partially filled with a fine mosaic of secondary calcite. **C.**—Subordinate colourless calcite of matrix in mosaics. **C′.**-Fibrous colourless calcite of matrix. **G.**—Part of a well-rounded clastic unit of Gaj limonitic-limestone. **G′.**—Parts of well-rounded clastic units from arenaceous beds of upper strata of Gaj limonitic-limestone.

tunity, by the way, to add the following specimens to the State Geological Collection :—

Date.	Registered No.	Provisional Name.	Locality and Remarks.
25-7-16	559	From Fossil-zone underlying Pindáralite No. 103.	Well-shaft just outside Dwárkadish Wari, Bokhira.
25-7-16	560	Recent Shells of Oysters, incrusting rocks of shore.	Strand of Meda Creek, Miáni. Not registered on 29-12-15.
25-7-16	561	Sub-recent Consolidated Shell sand of Raised-beach	Khari Khán. Top layers of No. 339.
25-7-16	562	Arenaceous Interbedded Gáj Limestone.	20 feet from top of well-shaft. Underlying No. 346.

Gaj Arenaceous-limestone.

REGD. NO. 562.—Beneath the deposits of Degám Stone, hard by the quarry-sites on the W. side of the village of Degám, the well-shafts show a considerable thickness of richly fossiliferous conglomerate of the Dwárka Group of beds, which in their turn overlie the Gáj (Miocene) strata; while interbedded among the latter there are a few thin layers of a hard and very arenaceous limestone of a pale grey colour and fine, uniform texture, from which the specimen now under consideration was taken.

Under the microscope, thin sections show a thoroughly recrystallised matrix of colourless calcite in mosaics of about $\frac{1}{700}$ inch across. In this are imbedded :—(i).—Numerous angular grains of colourless quartz, from $\frac{1}{40}$ to $\frac{1}{200}$ inch, or so in size. (ii).—Many frayed laths of colourless muscovite, from $\frac{1}{100}$ to $\frac{1}{60}$ inch long by about $\frac{1}{600}$ inch wide. (iii).—The blurred outlines of a goodly number of fragments of spines and other calcified areolar tissues of *Echinoidea* about $\frac{1}{100}$ inch across. (iv).—Occasional traces of the remains of entire tests and portions of *Foraminifera,—Rotalia, Miliolina,*—nearly $\frac{1}{100}$ inch in diameter. (v).—A very few irregularly shaped bits of the ectocysts of *Polyzoa,* also nearly $\frac{1}{100}$ inch across. (vi).—Stray grains of opaque, black magnetite, from mere specks up to $\frac{1}{300}$ inch in dimensions. Clastic units of this stone occur frequently in the consolidated shell-sands of the Dwárka Group of beds.

Yellow-ochre and the 'Light-red' of Commerce.

REGD. NO. 313.—Whatever may have been the origin of the yellow-ochre of commerce, from which the much esteemed pigment technically termed 'light-red,' is manufactured after due calcination, it is at least certain that the deposits of crude material found in Porbandar State, are indirectly due to the decomposition of laterite.

It has already been pointed out that the prevailing yellow colour of the Gáj limonitic-limestones can be distinctly traced to the breaking down of the neighbouring or underlying lateritic material, which becomes not only incorporated, but operates principally by staining the limestone more or less heavily with ferric hydrate. When this limonitic-limestone is exposed by denudation and reacted upon by meteoric waters, it naturally disintegrates into subsoil and soil, and, under favourable circumstances, among which prolonged aqueous saturation appears to be an important if not essential factor, changes gradually into a plastic condition, which upon becoming dry by seasonal changes yields the soft and easily pulverisable substance known as the yellow-ochre of commerce.

Yellow-ochre sites near Sakhpur and Palakra.

Only a couple of localities have, up to the present, been found in Porbandar State, where this kind of yellow-ochre is available ;—the one registered as No. 270,* in the neighbourhood of the Hathiáni Temple, $\frac{1}{4}$ mile ESE. of the small village of Sakhpur, and the other far more important site, lying approximately 1 mile E. by ESE. of Pálakra,† and cited above as No. 313.

Microscopic Examination of Yellow-ochre.

Under magnifying powers of 100 diameters or more, thin sections or powders mounted in canada-balsam shows that the material is mainly composed of excessively minute irregular granules of calcite more or less heavily stained with yellow hydrate of iron. The granules between crossed nicols exhibit only faint interference-tints,—iridescent greens and pinks of a high order ; but there are no indications of dolomitisation, and the rock is sometimes streaked or veined with a trifle of opaque-black iron-oxide. Even when tolerably compact the material admits of being crushed into an impalpable powder, and the dissociated granules of pigmented calcite can then be more readily measured under the microscope to show that they seldom exceed $\frac{1}{1000}$ inch across.

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* *Vide ut supra*, 'Narrative Report', pp. xcviii, ci.

† *Vide ut supra*, 'Narrative Report', pp. cxiii-cxv ; also p. 42.

PLATE LXIV.

Regd. No. 429.—Fig. 67.—Consolidated Shell-sand.

100 yards WSW. of Tunkra, Across Bedding.

Resolved by WATSON & SONS' $1\frac{1}{2}$ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

S.—Elongated chips of lamellibranchiate shells, showing clear traces of histologica structure. **S'.**—Longitudinal median section through shell of small gastropod. **G.**—Well-rounded clastic units of Gaj limonitic-limestone. **G'.**—Well-rounded clastic units from arenaceous beds of upper strata of Gaj limonitic-limestone. **F.**—Tests of rotaliform *Foraminifera*. **F'.**—Tangential section of foraminifer,—*Rotalia* sp. **L.**—Rounded fragment of nullipore, *Lithothamnion* sp. **Q.**—Minute grains of colourless quartz. **E.**—Empty spaces. **C.**—Colourless mosaics of secondary calcite. **C'.**—Fibrous secondary calcite of cementing matrix.

Group II.—The Dwarka Group of Beds.

The Dwarka Group of Beds in Porbandar State.

THESE DEPOSITS which have not yet been fully investigated, were so named by FEDDEN* on account of their best and most typical development in the Gaekwari Taluka of Okhamandal, which constitutes the extreme north-western promontory of the Province of Káthiáwár, and of which the sea-port town of Dwárka is the capital.

Conformity of the Gaj and Dwarka Groups of Beds.

Although the lithological characters of the Dwárka Group of beds are very varied, and in spite of the absence of any clearly determinable fossils therein which correspond with those of the underlying Gáj Group, their relations are 'probably one of conformity;'† and the age of their lower strata is therefore assigned to the Higher Tertiary; while FEDDEN further observes, that, "though the total thickness is inconsiderable, it may be possible eventually to divide the beds into sub-groups, or to mark off some of the later deposits as Pleistocene."‡ These later deposits, there is every reason to believe, are extensively developed in Porbandar State; and, under the names of 'Kunchri' and 'Degám-stone,'§ furnish an important share of locally used building-materials.

Sub-groups of the Dwarka Beds in Porbandar State.

For the sake of simplicity the Dwárka Group of beds, as they occur in Porbandar State, may be divided into two main sub-groups;—the first comprising many varieties of structure, but agreeing in being more coarsely textured and of showing evidences of having been deposited directly upon the underlying beds of Gáj limonitic limestone, upon the beach and shallows of the littoral zone; while the second sub-group, of finer texture, was manifestly deposited in deeper waters, and probably at an early period of the Pleistocene age. Other distinctions are, that the first sub-group presents a variety of textures and colours,—from exceedingly coarse to tolerably fine,—in shades of grey brown and sometimes quite black, and being composed principally of the comminuted shells of molluscs augmented by the remains of organisms of shallow-littoral habit, fragments of Gáj limonitic-limestone

* "Memoirs, Geol. Survey of India," Calcutta, 1884, Vol. xxi, Part 2, p. 51.

† "Manual of the Geology of India," 2nd Edition, Calcutta, 1893, p. 324.

‡ *Loco. citato*, p. 51.

§ *Vide ut supra*, 'Narrative report,' pp. cxvii, cxviii, cxx, cxxii; also pp. 43, 44 and *postea* p. 150.

and quartz grains, may be classified together as 'Consolidated Shell-sands,' of Pliocene age. These occur principally in the form of raised-beaches all along the coastal borderland of the State, and extend inland for variable distances,—6 to 9 miles,—being especially in evidence to the south of Porbandar City, in the form of a range of low hills, and underlying the sand and mud of the Great Salt Marsh. Modifications are also met with, which may be included in this sub-group, in the form of 'Coral-rock'; manifestly, the petrified relics of contemporary reefs.*

Consolidated Shell-sands of Pliocene Age.

'Kunchri' and 'Degám' stones, already alluded to, represent the second sub-group. They are essentially foraminiferal limestones of much finer texture, that have evidently been deposited in the deeper waters of the marine littoral, and cannot be distinguished, under the microscope alone, from the miliolites of later date; but their mode of occurrence in the field, directly overlying the strata of the lower Dwárka sub-group, serves to instantly separate them from the miliolites; while they also present a marked difference in geological structure, being mainly of the nature of flagstones, composed of laminæ, of from ¼ to 1 inch or more in thickness, of alternately coarse and fine texture. The coarsely textured laminæ, moreover, are generally indued with the rusty-coloured stains of iron, so that the rock exhibits a banded appearance and is liable to split asunder like a shale. Nevertheless, large blocks of from 9 to 12 inches in thickness, especially from the Degám sites, are generally available for building purposes, and much used for the foundations of dwelling-houses in Porbandar City; for it has been found that when laid horizontally, the stone is capable of withstanding enormous crushing strain.

Kunchri and Degam Foraminiferal Limestones of Early Pleistocene Age.

In confirmation of the observations recorded above, a few optical determinations of typical examples may now be given as follows:—

REGD. NO. 5.—Taken from a large block of medium textured 'Consolidated Shell-sand,' at high-tide mark, forming breakers on the beach, below the purlieus of the RÁNÁ SAHEB'S Palace, SE. of Porbandar City. The dominant constituent of this compact greyish stone, is exhibited by elongated, somewhat rounded fragments

Consolidated Shell-sand 'Breakers' on the Shore near the Rana Saheb's Palace.

* *Vide ur supra*, 'Narrative Report', pp. xcvi, xcvii, c, ci, cxl, cxli and 43.

Plate LXV.

Regd. No. 429.—Fig. 68.—Consolidated Shell-sand.

From another portion of the same preparation,—Fig. 67.

Resolved by WATSON & SONS' ½ *inch Objective*, 0·34 *Numerical Aperture.*

Amplified 50 Diameters.

To show the intimate structure of the cementing fibrous, secondary calcite, **C**, more clearly. The spaces, **E,** not being completely filled by opposing fibres from, **C′,** their terminals crystallise out in mosaics. **S.**—Elongated sections of the shells of lamellibranchs, showing clear traces of histological structure. **G.**—Well rounded clastic units of Gaj limonitic-limestone. **G′.**—Clastic unit of arenaceous Gaj limonitic limestone, evidently from the upper strata of the group of beds. **L.**—Rounded fragment of nullipore,—*Lithothamnion* sp. **F.**—Tangential sections of tests of rotaliform *Foraminifera*,—*Rotalia* sp. **E.**—Empty spaces.

of the shells of molluscs, the majority of which show histological structure with great clearness. Next in abundance, there are many well-rounded unmistakable small pebbles of Gáj limonitic-limestone, conspicuous by their yellow to brownish colours, fossil contents and general intimate structure.* These vary in sizes from about $\frac{1}{80}$ to $\frac{1}{25}$ inch across. The tests of *Foraminifera* are fairly well represented, while there are also recognisable rounded fragments of corals, spines and tissues of echinoids, and the ectocysts of *Polyzoa*. A few angular grains of quartz, from $\frac{1}{300}$ to $\frac{1}{400}$ inch, and stray pieces of colourless augite (diopside) may also be detected between crossed nicols. All of these clastic particles are cemented together mainly by secondary calcite in fine fibres radiating from them, but not always filling up the interspaces; while sundry portions are bound together by mosaics of the same mineral.

Consolidated Shell-sand on the W. Bank of the City Creek, Porbandar.

REGD. NO. 14.—On the W. bank of the city creek spanned by the bridge of the road to Ránáwáo from Porbandar, at the site shown by Fig. 6, Plate V, there is a good exposure of beds of Dwárka consolidated shell-sand, shown resting upon strata of Gáj limonitic limestone. The specimen under consideration, was taken from flaggy beds, overlying a coarser conglomeratic stratum, and is of coarser texture than No. 5, just described, as well as more thoroughly recrystallised and otherwise altered. The dominant elongated fragments of mollusc-shells, only occasionally show histological structure, their tissues having been for the most part, replaced by irregular plates of colourless calcite. It is clear that many of these chips of shells, must have been composed of the less stable form of carbonate of lime called aragonite; for as HARKER observes,† the process of recrystallisation has resulted in the development of a rather coarser mosaic within the shell-fragments, than that of the external binding matrix of secondary calcite; while a thin film of impurities is pushed outward to mark the original outlines of the chip. These chips frequently measure $\frac{1}{20}$ by $\frac{1}{100}$ inch in size.

Microscopic Structure of the Consolidated Shell-sand from the orbandar City Creek.

Many well-rounded small pebbles of yellow Gáj limestone often $\frac{1}{20}$ inch in diameter are conspicuous; while pieces of *Lithothamnion*,

* *Vide ut supra*, p. 143.

† 'Petrology for Students', Cambridge, 1908, p. 262.

$\frac{1}{80}$ to $\frac{1}{50}$ inch across; entire tests and broken bits of *Foraminifera*, $\frac{1}{100}$ inch or less; angular grains of clear quartz, $\frac{1}{200}$ to $\frac{1}{100}$ inch; and portions of the hard tissues of *Polyzoa* and *Echinoidea* are also present. The entire fabric is strongly recalcified; its cementing matrix being composed of a fine mosaic of clear, colourless calcite, which, however, leaves a few small interspaces every here and there.

Consolidated Shell-sands of Bhado Dhar.

REGD. NO. 148.—This specimen, presumably belonging to the lower sub-group of the Dwárka beds, was taken from the slopes of a low hillock called Bhádo Dhár, $1\frac{3}{4}$ miles SW. by SSW. of Bhárwára, resting upon the laterite at its SE., and overlapping a bed of Pindáralite of the Gáj Group at its NE. end.* It is peculiar in showing beds of light and dark hues varying from light and dark greys to purplish-brown and almost black colours, and coarse as well as fine textures. There can be no doubt that the unusual colours of the stone are due to ferric hydrate derived from the subjacent laterite; a somewhat similar effect, from like causes, being observed in the outcrop of 'Dwárka Shelly-limestone, No. 351, $1\frac{1}{4}$ miles SE. of Bábádeshwar Temple, near by the laterite formations of Simáni.†

Thin sections when subjected to microscopical examination, show a differentiation into at least a couple of varieties,—the light and the dark, as follows:—

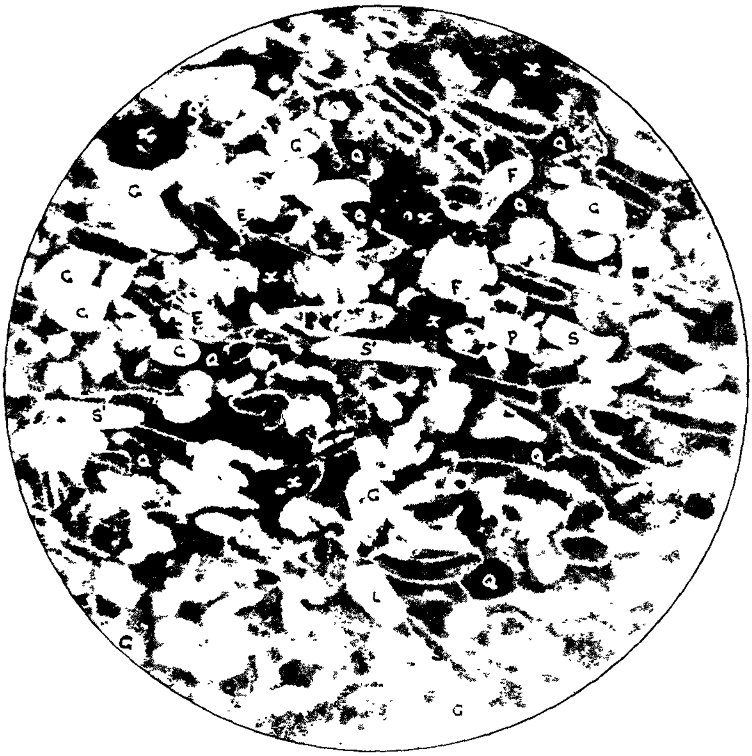
Microscopical Structure of the Light Variety of Stone from Bhado Dhar.

The light variety has, by recalcification, been practically converted into a mosaic of allotriomorphic crystals of colourless calcite, varying from $\frac{1}{50}$ to $\frac{1}{80}$ inch across. Some of these, exhibit twin lamellæ,—C', Fig. 61, Plate LVIII. The mosaic plates moreover, contain the shadowy recalcified remains of organisms,--chiefly the calcified areolar tissues of echinoids, and the tests of a few *Foraminifera*, principally a sub-spiral form, probably of the genus *Peneroplis*, slightly over $\frac{1}{100}$ inch in length, and a few rotaliform species. Throughout the field-of-view, there are many patches of translucent brown matter, frequently without definite outlines, and often covering parts of more than one mosaic unit. These are more than likely to be altered products derived from the decomposition of clastic particles of laterite, and of the nature of ferric hydrate stains; but some of them call to mind the flakes of palagonite, so common in the decayed remnants of vitreous

* *Vide ut supra*, 'Narrative Report', pp. lii, lvii.

† *Vide ut supra*, 'Narrative Report,' pp. cxxv, cxxv, cxxvi.

PLATE LXVI.



Regd. No. 474.—Fig. 69.—Consolidated Shell-sand.

Flagstone Quarry, 500 yards N. by NNE. of Rabarikhira, Balej.

Resolved by WATSON & SONS' $1\frac{1}{2}$ *inch Objective*, 0·17 *Numerical Aperture*.

Amplified 15 Diameters.

S.—Elongated chips of partially rounded lamellibranchiate shells showing traces of histological structure. **S'.**—Duplicates of, **S**, thoroughly recalcified. **G.**—Well-rounded clastic units of yellow to brown Gaj limestone. **F.**—Entire and fragmentary tests of *Foraminifera*,—chiefly *Rotalidæ*. **E.**—Spines and calcified areolar tissues of *Echinoidea*. **P.**—Ectocyst of a *Polyzoon*. **L.**—Rounded bit of the thallus of *Lithothamnion*. **Q.**—Angular as well as partially rounded grains of colourless quartz. **X.**—Empty spaces. All interspaces are filled with a well-developed mosaic of colourless secondary calcite.

igneous rocks. They are feebly refringent. Angular grains of colourless quartz are not of frequent occurrence, and of minute dimensions, $\frac{1}{150}$ to $\frac{1}{200}$ inch across. They, can, of course, be readily recognised between crossed nicols by their interference tints, which, in thin sections, give the whites, blue-greys and pale yellows of the first order. Lastly, by diligent searching, a few acicular scales of colourless muscovite,—measuring from $\frac{1}{40}$ to $\frac{1}{50}$ inch in length, and less than $\frac{1}{1000}$ inch transversely,—may be detected at irregular intervals; the position of one of these is indicated at M[1], Fig. 61, Plate LVIII. These exceedingly delicate laths, nevertheless show basal cleavages, extinguish straight, and give interference tints in pinks and greens of the third order.

Microscopical Structure of the Dark Variety of Stone from Bhado Dhar.

REGD. NO. 148.—Fig. 63, Plate LX, and Fig. 64, Plate LXI, are reproductions from photomicrographs, taken from two adjoining portions of the same thin section to display the structure of the dark variety of 'Consolidated Shell-sand' undoubtedly belonging to the Dwárka Group of beds, forming the low hillock called Bhádo Dhár.

It will be observed that the general structure of this sample apparently differs widely from that of the light variety; but in reality both are essentially the same, save for the manner of distribution of the decomposed products of laterite which determines the colour of the stone, and perhaps also in the difference of their foraminiferal tests, which probably belong to different zones of the marine littoral.

It may also be noticed that in the thoroughly re-calcified chips of lamellibranchiate shells, the calcite mosaics are considerably coarser than those of the interstitial authigenous matrix, the former measuring from $\frac{1}{200}$ to $\frac{1}{400}$ inch across, while the latter seldom exceed $\frac{1}{800}$ and average about $\frac{1}{1000}$ inch. It will also be seen that the impurities of deep brown iron-hydrate, are pushed out, to form quite a conspicuous border round the chip-pseudomorph. The tests of *Foraminifera* $\frac{1}{40}$ to $\frac{1}{30}$ inch; shell-chips, $\frac{1}{4}$ to $\frac{1}{20}$ inch; echinoid tissues, $\frac{1}{100}$ to $\frac{1}{50}$ inch, and quartz grains, $\frac{1}{150}$ to $\frac{1}{100}$ inch, are all relatively coarser than in the light variety, Figs. 61 and 62, thereby denoting sedimentation in a shallower zone of the marine littoral.

Variations in the Consolidated Shell-sands

REGD. NO. 410.—Just as the pebbles on the sea-shore or the shelly sands of the beach tend to be sorted by shiftings into coarser or finer lots of clastic units, so, when consolidated, the resulting stone is found in sedimentary rocks to vary in texture and frequently in composi-

tion, both horizontally and vertically, and a good case in point is furnished by the specimen of 'Consolidated Shell-sand' now under consideration.

The stone outcrops, at a considerable distance from the beach-breakers with which it is continuous, being isolated from the latter by blown-sand ; and can therefore be traced as part and parcel of the same deposits already described as 'Registered No. 5.'* Its site and mode of occurrence, uses, etc., have also been recorded† ; so that it now only remains to consider its intimate structure.

Microscopic Structure of the Consolidated Shell-sand to the S. of Chaya.

In preparing thin sections for microscopic examination, it is extremely difficult to secure complete slices, on account of the large quantity of siliceous sand, with which the calcareous stone is incorporated. As soon as the slice becomes thin enough to distinguish the nature of its component parts, the hard quartz grains are torn out of their places, leaving only a few remnants in the otherwise vacant spaces ; and as these spaces preponderate, it may be taken for granted that they were once filled with quartz. The spaces are usually of irregular shapes, and those of them that are still filled with the colourless quartz, show, between crossed nicols, that the individual grains, had been subjected to great strain, being shattered in all directions, so that the units of quartz, when thinly sliced simply drop out in small pieces. That the cracks are not the result of the mechanical methods employed in preparing the thin sections, is evidenced by the fact that they are filled with secondary silica, and therefore clearly of old standing. The quartz units in this specimen vary in size from less than $\frac{1}{50}$ to more than $\frac{1}{30}$ inch across.

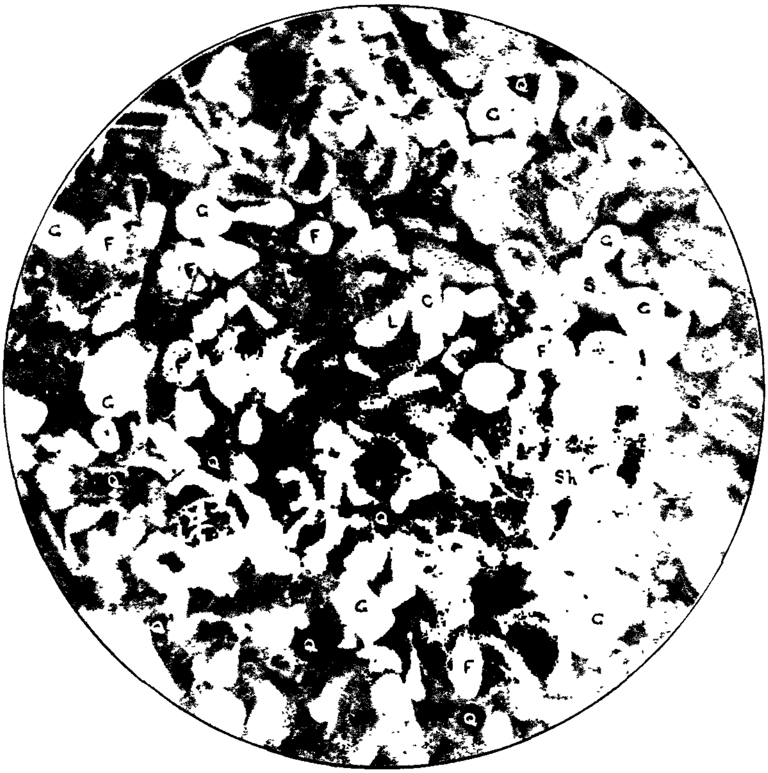
Next in order of abundance there come many well-rounded units of a very arenaceous limestone, which stongly resemble if they are not identical with portions of certain interbedded strata already described as No. 562.‡ These usually give elliptical sections, of tolerably uniform sizes,— $\frac{1}{30}$ by $\frac{1}{50}$ inch. The shells of molluscs, chiefly *Lamellibranchiata*, $\frac{1}{30}$ by $\frac{1}{60}$ inch, on an average, show marked traces of histological structure ; while the less frequent tests of *Foraminifera*, sometimes large, but more usually small, measure from $\frac{1}{60}$ to as much as $\frac{1}{10}$ inch across, and are principally represented by members of the family *Rotali-*

* *Vide ut supra*, p. 150.

† *Vide ut supra*, 'Narrative Report.' pp cxxxvii-cxxxix.

‡ *Vide ut supra*, p. 147.

PLATE LXVII



Regd. No. 474. –Fig. 70.—Consolidated Shell-sand.

Flagstone Quarry, 500 yards N. by NNE. of Rabarikhira, Balej.

Resolved by WATSON & SONS' 1½ *inch Objective*, 0.17 *Numerical Aperture.*

Amplified 15 Diameters.

S.—Recalcified chips of shells of *Lamellibranchiata*. **S.**—Chips of shells showing traces of histological structure. **Sh.**—Longitudinal median section through shell of small gastropod. **F.**—Tests of rotaliform *Foraminifera*. **F.'**—Test of *Miliolina*. **G.**—Well-rounded clastic units of yellow to brown Gaj limestone. **E.**—Fragment of calcified areolar tissue of echinoid. **L.**—Portion of thallus of *Lithothamnion*. **Q.**—Angular as well as partially rounded grains of quartz. **X.**—Empty spaces. All interspaces are completely filled with a well developed mosaic of colourless calcite.

dæ. Subordinate units, are fragments of corals, the spines and tissues of echinoids, *Polyzoa* and nullipores. All of these are closely crowded together, so as to leave but little room for a very small proportion of cementin; secondary calcite in minute, irregular, colourless granules.

Consolidated Shell-sand of Tunkra suitable for large Building-blocks.

REGD. NO. 429.—This specimen, taken from the sound stone at the base of a small pit-quarry, about 100 yards WSW. of the village of Tunkra, is closely similar in intimate structure to the excellent stone registered as No. 5,* but has the advantage of being well situated for quarrying on a large scale, although no attempt has yet been made to utilise the material except for small local needs. There are evidences† to show that the stone exists in large quantities throughout the neighbourhood of Tunkra, and is available in solid blocks of sizes large enough for all kinds of building construction.

Microscopical Structure of the Consolidated Shell-sand of Tunkra.

Under the microscope, the structure of the stone is clearly shown by the excellent reproductions from photomicrographs taken from thin sections, both parallel with and at right angles to the plane of bedding :—Fig. 65, Plate LXII ; Fig. 66, Plate LXIII ; Fig. 67, Plate LXIV and Fig. 68, Plate LXV. It will be seen from these accurate pictures, that the clastic units are of a very varied character ; being derived from pre-existing rocks, both near and far distant from the site of sedimentation, and that these particles are held firmly together by secondary calcite of two kinds :—incipient fibres, and allotriomorphic grains, the latter of which, in section, present the outlines of a fine mosaic. Occasionally, when the fibres of calcite, which radiate from the clastic units, do not meet in the interstitial space, a kind of miarolitic cavity is formed, and the terminals of the fibres crystallise out into grains like those of the mosaics.

Fibrous Character of the Secondary Calcite in the Consolidated Shell-sand of Tunkra.

Clastic Units of the Consolidated Shell-sand of Tunkra.

The clastic units, in order of importance comprise :—(i).—Elongated, rounded chips of the shells of lamellibranchiate or bivalve molluscs, which usually show clear traces of histological structure, but are sometimes entirely replaced by calcite. (ii).—A few complete shells of small gastropods and fragments of larger members of the same

* *Vide ut supra*, p. 150.

† *Vide ut supra*, 'Narrative Report', pp. cxliv, cxlvii.

class of molluscs. These shelly constituents vary very considerably in sizes :—the elongated chips from $\frac{1}{20}$ to $\frac{1}{10}$ inch or so long, by about $\frac{1}{100}$ to $\frac{1}{60}$ inch broad. (iii).—Most conspicuous are the well-rounded units of Gáj limonitic limestone, identifiable by their yellow to ruddy brown colour and fossil contents, and frequently varied by similar units (full of minute angular particles of quartz) which were probably derived from the thin arenaceous beds intercalated with the upper strata of the group. These units are more uniform in sizes, varying from $\frac{1}{50}$ to $\frac{1}{15}$ inch across. (iv).—Entire tests and fragments of *Foraminifera,* frequently exhibiting structural details, and measuring as much as $\frac{1}{14}$ inch across. (v).—Partially rounded pieces of *Lithothamnion.* (vi).—A very subordinate representation of bits of corals, *Polyzoa,* and echinoids. (vii).—A few grains of quartz, which are peculiar in being fairly well-rounded, and of showing signs of having been shattered, and mended by emanations of secondary silica. These seldom exceed $\frac{1}{100}$ inch across. (viii).—Lastly, almost every thin section examined, was found to hold one or more small irregular fragments of much decayed granophyre, showing micropegmatite.

False-bedded Flagstones of the Bhadar-River-Creeks at Navibandar.

REGD. NO. 455.—That slight variations constantly occur among the 'Consolidated Shell-sands' of the coast-line in Porbandar State, is well exemplified by the specimen now under consideration, which was taken from a very fine outcrop of solid-looking, false-bedded flagstones on the SW. bank of the Bhádar-River-Creek, about ½ mile NW. by WNW. of the town of Navibandar.* The stone is of very compact, and manifestly uniform texture, more arenaceous than usual, and would be available in thick slabs of large dimensions if it were not for its unfavourable situation by the side of the creek-bank, which would make quarrying on a large scale undesirable.

Closely crowded Clastic Units in the Consolidated Shell-sand of the Bhadar-River-Creek.

Save for a very few extra large clastic units, the rock is composed of tolerably uniform-sized particles ; but these are so closely crowded, that little or no interstitial spaces are left. These, when present, are filled with an excessively fine granular calcite, showing faint traces of a fibrous tendency, and occasionally developing into a matrix of minute mosaics of secondary calcite, scarcely discernible with a magnifying power of 50 diameters.

* *Cf. ut supra,* 'Narrative Report', pp. clv, clix.

Plate LXVIII.

Regd. No. 345.—Fig. 71.—Foraminiferal Flagstone.

Roadside Exposure, 1½ miles WSW. of Degam.

Resolved by Watson & Sons' 1½ *inch Objective*, 0·17 *Numerical Aperture.*

Amplified 15 Diameters.

F.—Perforate test of foraminifer,—*Globigerina* sp.—with pseudo-oolitic border. **F′.**—Single perforate chamber of test of foraminifer,—*Globigerina* sp —filled with amorphous calcite deeply stained with ferric hydrate. **G.**—Well-rounded clastic units of Gaj limonitic-limestore. **X.**—Amorphous rounded nuclei of lime with single pseudo-oolitic border. **X′.**—Pellets of amorphous lime with more than one pseudo-oolitic border. **S.**—Chips of the shells of *Mollusca*, a few of which show traces of histological structure. **C.**—Colourless mosaic of secondary calcite completely filling all inter-spaces. **C′.**—Mosaics of secondary calcite pseudomorphs after organic remains. **E.**—Portion of spine of an echinoid. **L.**—Section of thallus of a nullipore. There are no quartz grains in this field-of-view.

The clastic units are principally of organic origin, but there is a plentiful representation of colourless quartz grains of irregular angular and sometimes rounded shapes, varying in size from less than $\frac{1}{200}$ to a little over $\frac{1}{100}$ inch across. Rarely, a few minute grains of green augite,—$\frac{1}{300}$ inch and less,—may be detected.

Other constituents include :—(i).—A good many short and thick chips of lamellibranchiate shells, about $\frac{1}{[illegible]}$ by $\frac{1}{150}$ inch in dimensions on an average ; but occasionally as much as $\frac{1}{15}$ inch long. Some of these units show clear traces of histological structure, while others are completely recalcified. (ii).—The tests of *Foraminifera* are well represented by rotaliform species, from $\frac{1}{100}$ to $\frac{1}{60}$ inch or slightly more across ; but there are also a few much larger forms to be found in nearly all thin sections,—notably of a *Miliolina*, $\frac{1}{15}$ inch in length. (iii).—A few characteristically yellow and brownish well-rounded units, $\frac{1}{50}$ inch or so across, proclaim the presence of particles of Gàj limonitic-limestones (iv).—Subordinate units occur in the form of small fragments of corals echinoid tissues, and irregularly shaped or rounded bits of *Polyzoa* and *Lithothamnion*, varying in sizes from less than to a trifle over $\frac{1}{100}$ inch in major diameter.

Sound Character of the Consolidated Shell-sand immediately E. of the Village of Mulmadhavpur.

REGD. NO. 490.—In a neighbourhood where sound and strong building-stone is scarce, and the inhabitants are driven to go far for their building materials or put up with the soft inferior blocks of consolidated blown-sand so largely developed locally, it is somewhat surprising that the considerable outcrop of compact and durable stone within 100 yards E. of the village of Mulmádhavpur, from which this specimen was secured, should lie practically untouched.*

In this variety of ' Consolidated Shell-sand ' of the Dwárka Group, the clastic units are not so closely compacted as to leave but little space for an authigenous cementing material, but are usually disposed so far apart from one another as to allow for the deposit of more than the usual proportion of secondary calcite. This secondary calcite, moreover, is peculiar, from the fact that it forms an appreciably deep border of infinitesimally small granules around each clastic unit, and sometimes foreshadows radiating fibrous structure. When the borders from contiguous units meet, they generally develop a narrow median layer of minute,

* *Cf. ut supra*, ' Narrative Report ', pp. clxvi, clxx.

colourless mosaics of calcite ; while at other times the mosaic lines the inner walls of a kind of diminutive drusy cavity.

Clastic Units of the Consolidated Shell-sand of Mulmadhavpur.

The clastic units, as usual, are nearly all of organic origin, with the exception of a rather abundant proportion of colourless angular quartz grains, which measure from less than $\frac{1}{200}$ to fully $\frac{1}{100}$ inch across. The organic units comprise :—(i).—Elongated chips of lamellibranchiate shells and small pieces of the shells of gastropods, some of which show histological structure, while others are thoroughly recalcified. The former average about $\frac{1}{60}$ by $\frac{1}{200}$ inch in dimensions. (ii).—A good many tests of small *Foraminifera*, *Rotalia* sp., and *Globigerina* sp., about $\frac{1}{150}$ inch or so in diameter, and a few larger tests of *Miliolina*, $\frac{1}{65}$ inch in length. (iii).—A fairly large number of well-rounded, yellow to brown units of Gáj limonitic-limestone, from $\frac{1}{200}$ to $\frac{1}{100}$ inch across. (iv).—Occasional irregularly-shaped fragments of the spines and calcified areolar tissues of *Echinoidea*. coralla of *Madreporaria*, ectocysts of *Polyzoa* and the thallus of *Lithothamnion*.

Consolidated Shell-sand of Rabarikhira Khan near Balej.

REGD. NO. 474.—The locality, mode of occurrence and uses of this stone have already been noted ;* but it may here be added that the material, after examination in the laboratory, does not resemble the Kunchri-stone, but belongs unquestionably to the lower sub-group of the Dwárka beds. The stone, moreover, is interesting, inasmuch as it contains a larger variety than usual of the tests of *Foraminifera*, in an excellent state of preservation ;—as will be gathered from the following microscopical determinations :—

Clastic Units of the Consolidated hell-sand of Rabarikhira Khan.

(i).—Partially rounded chips of the shells of lamellibranchiate *Mollusca*, many of them showing clear traces of histological structure, while others are completely recalcified, are represented in abundance ; there are undoubtedly also fragments, and a few very minute entire shells of gastropods. The bivalve chips vary from $\frac{1}{40}$ to $\frac{1}{60}$ inch long, by about $\frac{1}{150}$ inch broad. (ii).—The tests of *Foraminifera* include many rotaliform species, varying from $\frac{1}{10}$ to $\frac{1}{60}$ inch across the entire tests ; a few tests of *Textularia*, *Miliolina* and *Nodosaria*. (iii).—Many well-rounded clastic units of yellow, orange and brown Gáj limestone. (iv).—Rounded pieces of the thallus of

* *Cf. ut supra*, 'Narrative Report', pp clxi. clxiii.

PLATE LXIX.

Regd. No. 345.—Fig. 72.—Foraminiferal Flagstone.

Central Portion of Fig. 71, more highly Magnified.

Resolved by WATSON & SONS' ½ *inch Objective*, 0·34 *Numerical Aperture*.

Amplified 50 Diameters.

F.—Perforate test of foraminifer,—*Globigerina* sp.—with single pseudo-oolitic border. **F′.**—Single perforate chamber of test of larger foraminifer,—*Globigerina* sp.—without border. **G.**—Rounded clastic units of Gaj limonitic-limestone. **X.**—Indeterminate rounded nuclei of amorphous lime with single pseudo-oolitic envelope. **X′.**—Indeterminate rounded nuclei of amorphous lime with more than one pseudo-oolitic envelope. **C.**—Colourless mosaic of secondary calcite completely filling all interspaces. **C′.**—Pseudomorphs in mosaics of colourless secondary calcite of organic remains. **S.**—Recalcified chips of shells of *Mollusca*. **L.**—Section of thallus of *Lithothamnion*.

Lithothamnion. (v).—Bits of branched and astræan corals. (vi).—Irregular and rounded fragments of the calcified areolar tissues of *Echinoidea.* (vii).—Occasional pieces of the ectocysts of *Polyzoa.* (viii).—Angular as well as rounded grains of colourless quartz. (ix).—A few small crystals of opaque black magnetite. The appreciable interspaces between these clastic units, are completely filled by a well developed mosaic of colourless secondary or recrystallised calcite.

Fringing Coral-reefs of Plio-Pleistocene date in Porbandar State.

In the Narrative Report records have been made of the existence of fringing coral-reefs during the period,—Plio-Pleistocene,—of the deposition of the Dwárka Group of beds in Porbandar State.* Especially noteworthy, is the existence, *in situ*, of a well-preserved coral-reef near the mouth of Visáwára Creek,† where the coralla, chiefly those of the sub-order *Madreporaria*, appear to be as fresh as specimens of recent growth. Farther inland, however, where the raised-beach has been deeply covered by subsequent calcareous deposits, the coralla become so thoroughly recalcified, as to lose nearly all traces of histological structure, and it is in this condition that the original reef, clogged with the remains of minute organisms, such as *Foraminifera*, and small fragments of *Polyzoa*, *Echinoidea*, nullipores, and grains of quartz, assumes the character of a 'Coral-rock', which has been recorded as occurring at several widely separated places ;—Bhávpura, Miáni, Cháya and Rángháwáo, and registered respectively as Nos. 254, 260, 408 and 413.

The Upper Strata or Sub-group of the Dwarka Beds in Porbandar State.

The upper strata of the Dwárka Group of beds in Porbandar State, which have here been classified as a Sub-group, probably of early Pleistocene age,‡ differ markedly from the foregoing series of consolidated shell-sands ; and, under the microscope, alone, cannot be distinguished from the miliolites or later Pleistocene deposits. The clastic units of these rocks, which are typically represented by the well-known building-stones of Kunchri and Dégam, and which are structurally similar to those of the miliolites, would doubtless be erroneously described, as were those of the latter, as *oolitic*.§ As a matter of fact

* *Vide ut supra*, 'Narrative Report', pp xcvi, xcvii, c, ci, cxxxvii, cxxxix, cxl, cxli.

† *Cf. ut supra*, 'Narrative Report', pp. cvi, cvii, cxi, cxii.

‡ *Cf. ut supra*, p. 149.

§ 'Manual, Geology of India', 2nd Edition, Calcutta, 1893, p. 395

the clastic units of the stone, when carefully scrutinised, have evidently, by recalcification, formed a slight border of colourless mosaics of calcite, which, as usual, have thrust sundry impurities to their outer edges,* thereby giving rise to a kind of coating which has been mistaken for an oolitic concretion.

Kunchri-stone.

REGD. NO. 327.—Commercially known as 'Kunchri-stone' after the locality from which it is excavated, the megascopic characters and uses of this inferior variety have already been recorded; † but, upon examination in the laboratory, the material, which to the naked eye, appears to be azoic, is shown to be essentially of organic origin, being composed of alternately coarse and finely textured, thick and thin laminæ, with a tendency to decompose along the interlaminary planes, and to split into slabs or flagstones.

Clastic Units of the Foraminiferal Flagstone of Kunchri.

(i).—So thoroughly recalcified has this rock become, that it is difficult and sometimes impossible to determine the true nature of the majority of its clastic units, which assume spherical and ellipsoidal shapes. These units show granular, grey, amorphous nuclei, surrounded by a thin selvage of colourless calcite mosaics and enveloped in a pellicle of darker almost ultramicroscopic particles of impurities. Sometimes, a second envelope of emanations is present, and lends support to the statement that the grains are *oolitic concretions.* According to the position of these units in the coarse or finely-textured laminæ, they vary from about $\frac{1}{100}$ to $\frac{1}{50}$ inch in the coarser and $\frac{1}{300}$ to $\frac{1}{100}$ inch across in the more finely-textured layers; and these measurements hold good more or less with reference to units the precise nature of which can be identified. (ii).—Many of the clastic units, by their outlines, colour, or traces of structure admit of being determined under the microscope. They show a tolerable abundance of well-rounded particles of yellow, fossiliferous Gáj limestone; entire and fragmentary tests of *Foraminifera,—Rotalia, Miliolina, Textularia*; occasional pieces of spines and the calcified areolar tissues of *Echinoidea,* the ectocysts of *Polyzoa,* coralla of *Madreporaria* and thallus of *Lithothamnion.* There are also a few chips of the shells of *Mollusca,* mostly thoroughly recalcified, but occasionally showing faint traces of histological structure; while minute, colourless, angular and partially-rounded grains of quartz,—$\frac{1}{300}$ to $\frac{1}{200}$ inch across,—can be detected

* *Vide* DR. HARKER'S 'Petrology for Students', 4th Edition, Cambridge, 1908, p. 262.

† *Vide ut supra,* 'Narrative Report', pp. cxvii, cxviii, cxxi.

PLATE LXX.

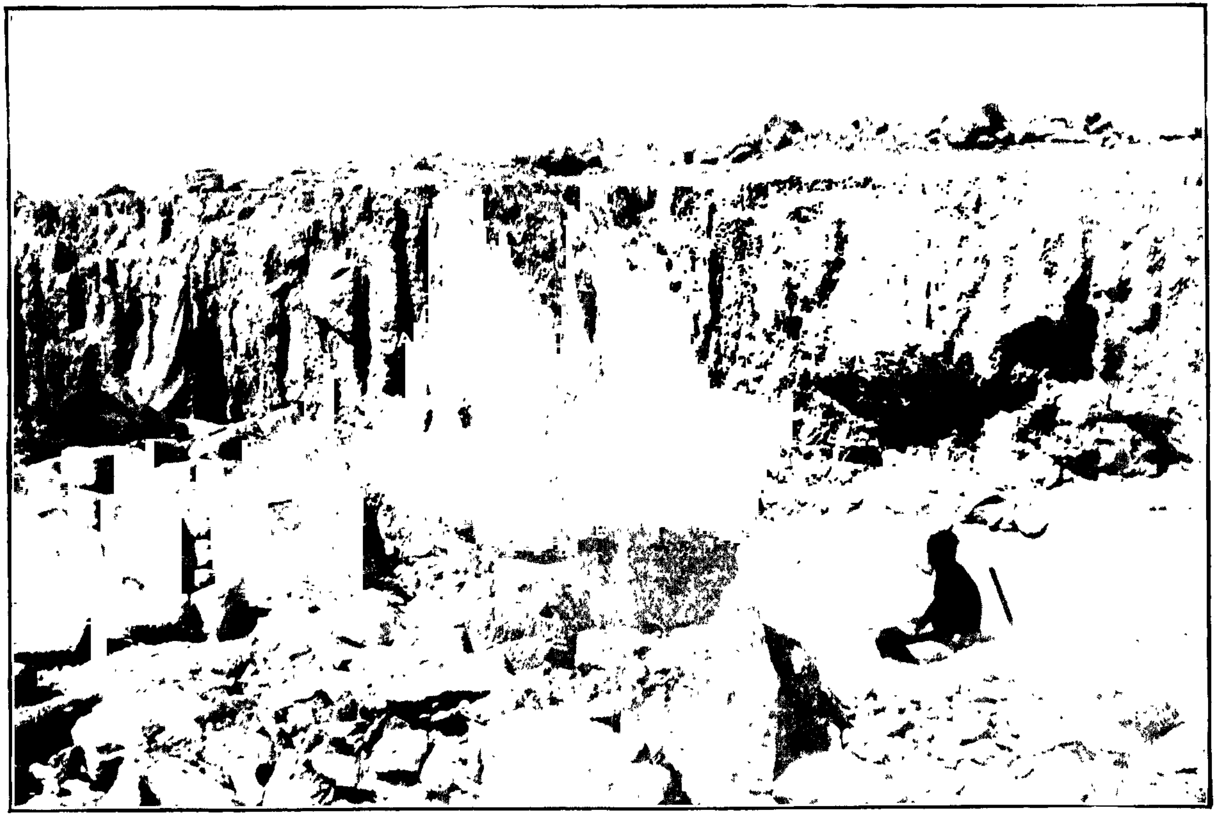


Fig. 73.—Sub-recent Consolidating Shell-sand of Raised Beach.

Khári Khán, ¾ mile W. of Kunchri.

From a *Photograph* taken on 25th July, 1916, by E. HOWARD ADYE, F.G.S. **A.**—Shows the meshwork of rock consolidating through the agency of carbonated percolating meteoric waters. **B.**—Consolidated stone at depth of 10 feet, being quarried for building-blocks, shown piled on the left-hand side of the picture.

as sparingly present, between crossed nicols. (iii).—The rock has been so decidedly recalcified, that all interspaces are filled with a well-developed mosaic of colourless secondary calcite. The specimen may therefore be called a 'Foraminiferal Flagstone.'

Degam-stone.

REGD. NO. 345.—The type of 'Foraminiferal Flagstone' just described, finds finer development in the surroundings of the neighbouring village of Degám, where it is extensively extracted for building purposes and is almost entirely consumed within the State.* Its microscopical structure, which is essentially similar to that of the later deposits of 'Miliolite'† is very clearly shown by the photomicrographic reproductions, Fig. 71, Plate LXVIII and Fig. 72, Plate LXIX. From these it will be observed that the texture of the stone is practically uniform, in the finer and more compact layers, which often attain to several inches in thickness. In the alternating coarser layers, the clastic units are not quite so uniform in sizes, and are, of course, of relatively larger dimensions. It will likewise be noticed that the texture has been very thoroughly recalcified ;—the colourless mosaics of calcite being defined with the utmost clearness, and completely filling all interspaces as well as invading the substance of the clastic units, which latter may be enumerated as follows :—

Clastic Units of the 'Foraminiferal Flagstone' of Degam.

(i).—The majority of the clastic units have been so much altered by recalcification, that it would be impossible to determine their origin, beyond assuming from their spherical, ellipsoidal and rounded elongated shapes, that they are all of organic origin. (ii).—When deeply stained with yellow or brown hydrate of iron, and exhibiting faint traces of fossil remains, it is reasonable to believe that they were derived from the underlying beds of Gáj (Miocene) limestone. (iii).—Unmistakable units of entire and fragmentary tests of *Foraminifera* give a distinctive character to the rock, which has therefore been styled a 'Foraminiferal Flagstone.' Among these delicate organic remains, it is easy to identify members of the families *Globigerinidæ, Rotalidæ, Textularidæ* and *Miliolidæ*. (iv).—Elongated as well as abbreviated chips, occasionally showing traces of histological structure, denote the inclusion of bits of the shells of both lamellibranchiate and gastropodous *Mollusca,* which are fairly well represented. (v).—In subordinate

* *Cf. ut supra,* 'Narrative Report', pp. cxx, cxxii.

† *Vide ut supra,* p. 90. *et sequentes.*

proportion there may be recognised irregular as well as rounded fragments of the spines and other calcified areolar tissues of *Echinoidei*, the ectocysts of *Polyzoa*, the coralla of *Madreporaria* and the thallus of *Lithothamnion*. (vi).—Minute angular grains of colourless quartz are extremely rare, and seldom exceed $\frac{1}{100}$ inch across ; while the average sizes of the other clastic units vary from less than $\frac{1}{100}$ to a trifle over $\frac{1}{50}$ inch in major diameter.

PHYLUM E.—SUB-AERIAL ROCKS.

Sub-aerial Rocks.

INDUBITABLE PROOFS of the sub-aerial origin of some of the rocks of the coastal borderland in Porbandar are fortunately available among the Sub-recent and Recent deposits of the State ; but of the older formations which must have consolidated under similar circumstances, evidences are naturally wanting ; and cannot, in the present state of our knowledge, be satisfactorily supplied solely by means of laboratory research. It must therefore suffice, for the time being, to place on record a few observations made in the field, supplemented by notes on determinations made through the microscope.

Sub-aerial rocks may be divided according to their modes of origin, into two principal groups :—(i).—Consolidating Raised-beaches, and to a less degree of River-terraces and Concretionary deposits. (ii).—Consolidated Blown-sands.

Sub-aerially Consolidated Shell-Sand of Khari Khan near Kunchri.

In illustration of the first group, no better example could be afforded than the interesting series of pit excavations, still desultorily being exploited along the sea-shore, from the immediate NW. of Porbandar City for a distance of about 4 miles, to the neighbourhood of Khimeshwar Temple on the sand-dunes near Kunchri. The pits nearest to the Temple called Khári Khán, yield building-blocks of a loosely consolidated shell-sand, the mode of occurrence of which has already been sufficiently detailed.* This is clearly shown by the photograph here reproduced as Fig. 73, Plate LXX.

Clastic Units of the Khari Khan Stone.

Under the microscope, thin sections of the consolidated stone show a very coarse texture composed chiefly of the shells of *Mollusca*, that have undergone only slight changes, together with fragments of corals, echinoids, sea-mats, nullipores and a good many large tests of rotaliform *Foraminifera*, measuring from $\frac{1}{30}$ to $\frac{1}{50}$

* *Vide ut supra*, 'Narrative Report', pp. cxix, cxx, cxxii.

inch across. Minute grains of angular quartz doubtless occur in abundance; but are apt to drop out of thin sections during the processe of preparation. They can, however, be collected in abundance, and satisfactorily examined by Dr. SORBY'S methods.* The interspaces between the clastic units are seldom entirely filled with secondary calcite; but each unit is usually coated with a thin border of minute granules of colourless calcite.

Consolidated Blown-sands of Porbandar State.

The second group belonging to this phylum, is represented in Porbandar State by many extensive deposits of consolidated blown-sands, some of which are so sound and strong as to be highly esteemed by local builders and contractors for the erection of dwellings. Indeed, a very large number of even the better classes of houses in Porbandar City are mainly constructed from this kind of stone; which, it is scarcely necessary to add, is sold at much lower rates than even the inferior grades of miliolite-limestone.

'Chaya-stone.'

REGD. NO. 401.—This specimen† has been chosen as typical of the consolidated blown-sands, so extensively quarried on the heights of Cháya, because of its having been indurated by sunbaking to such an extent as to render it suitable for being cut and ground into sufficiently thin sections without fear of falling to pieces. The stone from lower levels, has been found to be structurally similar in all respects; but is much too soft and incoherent, when freshly excavated, to permit of being cut and ground without first being impregnated with a hardening medium.

Importance of the sizes of Clastic Units in Distinguishing between Rocks of Sedimentary and Subaerial Origin.

It may be remarked at the outset, that the main distinction between a sub-aerially consolidated blown-sand and its sedimentary counterpart, lies in the sizes of its clastic units; for it stands to reason that, under ordinary everyday circumstances, only the smaller and lighter particles would be wind-borne to accumulate as coastal and inland dunes, and there to undergo subaerial consolidation by a combination of superincumbent stress and the reactions of carbonated meteoric water. It is thus important that in investigations of this kind, a record of the condition, (entire, fragmentary, fresh, altered or decayed), and approximate sizes of the different constituents should be carefully made and kept for future reference.

* *Q. J. G. S.*, Vol. xxxvi, 1880.

† *Vide ut supra*, 'Narrative Report', pp. cxxxv, cxxxvi, cxxxviii.

'Cháya-stone' when cut into thin sections and examined under the microscope is found to bear out the abovenoted statement in every particular. Its clastic units are tolerably uniform in size, *i.e.*, about $\frac{1}{100}$ inch approximately across, and therefore not too heavy to be wind-borne for considerable distances inland. They are not very closely crowded, so that comparatively wide interspaces are left, in which a fine mosaic of clear, colourless, secondary calcite is deposited by the agency of percolating carbonated meteoric waters ;—and herein lies the main difference between this subaerially consolidated rock and deposits, like the miliolites, which are of true sedimentary origin.

Microscopes, of course, cannot be used for the purpose of distinguishing between authigenous constituents of sub-aerial and sedimentary origin; but by their means, other and more subtle distinctions are revealed, which may assist in determining the circumstances under which the rock took solid form ;—(i).—The clastic units show no tendency to develop pseudo-oolitic emanations. (ii).—They are generally of such diminutive sizes, either entire or fragmentary, as to be easily wafted by light breezes to accumulate as dunes, while the larger and heavier particles are left behind upon the beach.

Clastic Units of the Consolidated Blown-sands of the 'Chaya-heights.'

Clastic units in the 'Cháya-stone' comprise :—(i).—A few entire tests of *Foraminifera,—Miliolina, Operculina, Peneroplis,*—and fragments of larger rotaliform species, very few of which exceed $\frac{1}{100}$ inch across. (ii).—Chips of the shells of *Mollusca,* seldom longer than $\frac{1}{100}$ inch. (iii).—Well-rounded particles of yellow to brown Gáj limestone, barely more than $\frac{1}{100}$ inch in major diameter. (iv).—Subordinate fragments, either rounded or of irregular shapes, and generally less than $\frac{1}{100}$ inch in dimensions, of pieces of the coralla of *Madreporaria,* the calcified areolar tissues of *Echinoidea,* the ectocysts of *Polyzoa* and the thallus of *Lithothamnion.* (v).—A very few specks and granules of magnetite, rarely more than $\frac{1}{400}$ inch in size. (vi).—Angular, but sometimes partially rounded, colourless grains of quartz, in tolerable abundance, varying from $\frac{1}{400}$ to as much as $\frac{1}{100}$ inch in longest diameter.

REGD. NO. 482.—Consolidated blown-sands of sub-aerial consolid-

Consolidated Blown-sands of Porbandar State.

ation are, in addition to that of Cháya, of frequent occurrence along the SE. coastal borderland,* and are also found forming small isolated knolls where the material has been carried farther inland †. They are, however, of a brownish-grey colour and commercially inferior to the lighter-hued and almost white stones of the Cháya-heights.

Fairly typical of these accumulations, and by reason of its more extensive development and widespread local use for the erection of stone walls and the poorer classes of dwellings, is the specimen now under consideration ; which was taken from the indurated exposed top of the east end of the large open quarry called ' Bábudi Khán,' situated ½ mile ESE. of the sea-side town of Mádhavpur.—A, Fig. 31, Plate XXIX.

Under the microscope, the large and miscellaneous collection of small clastic units, may be seen to be more closely crowded than those of the kindred Cháya-stone. The cementing matrix as usual, consists of very minute grains of secondary, colourless calcite in form of a mosaic ; which, in the lower layers from which the building-stone is taken, is not particularly compact. The stone is consequently full of irregular pores and not so strong and durable as it would otherwise be.

Clastic units are, as already noted, of an unusually miscellaneous character. They are, taken together, of fairly uniform sizes, ranging from less than $\frac{1}{300}$ to as much as $\frac{1}{60}$ inch in longest diameter ; but it may be remarked, that the larger sized particles, such as scales of palagonite, the chips of *Mollusca* and certain of the entire tests of *Foraminifera*, are of an attenuated character, and accordingly very light in weight.

Clastic Units of the Consolidated Blown-sand of ' Babudi Khan ' near Madhavpur.

Determinations under the microscope, coupled with micrometric-measurements give the following results :—(i).—Entire tests and fragments of *Foraminifera*, among which may be recognised *Miliolina*, *Operculina*, *Peneroplis* and a few rotaliform species, vary from $\frac{1}{120}$ to $\frac{1}{60}$ inch in longest diameter. (ii).—Well-rounded units of yellow to brownish pellets of Gáj limestone ;—$\frac{1}{150}$ to $\frac{1}{100}$ inch across. (iii).—Elongated chips and short fragments of the shells of *Lamellibranchiata* and *Gastropoda* ;—$\frac{1}{100}$ to $\frac{1}{60}$ inch in length by

* *Vide ut supra*, 'Narrative Report ', pp. cxli, cxlii, cxlv-cxlvii, clxiv, clxv, clxvii, clxxi.

† *Vide ut supra*, ' Narrative Report ', pp. clxviii-clxxi.

about $\frac{1}{200}$ inch in breadth. (iv).—Small spines and pieces of the other calcified areolar tissues of *Echinoidea* ;—$\frac{1}{200}$ to $\frac{1}{80}$ inch in diameter. (v).—Irregularly shaped bits of the coralla of both branched and astræan *Madreporaria* ;—about $\frac{1}{100}$ inch. (vi).—Partially rounded portions of the thallus and branches of *Lithothamnion* ;—not much exceeding $\frac{1}{100}$ inch. (vii).—Scales of greenish, yellow and ruddy-brown semi-transparent vitreous material, probably of the nature of palagonite ;—about $\frac{1}{60}$ by $\frac{1}{100}$ inch. (viii).—Occasional, much decomposed fragments, showing traces of the ground-mass structure of basalt ;—barely $\frac{1}{100}$ inch across. (ix).—A few particles of irregularly shaped angular fragments of yellowish-brown augite ;—about $\frac{1}{100}$ inch. (x).—Sundry isolated colourless crystals, with yellowish cracks, of olivine ;—$\frac{1}{150}$ to $\frac{1}{100}$ inch in length. (xi).—Opaque black magnetite in specks and sporadic grains ; $\frac{1}{400}$ to a trifle over $\frac{1}{200}$ inch across. (xii).—A tolerably large proportion of angular grains of colourless quartz, ranging from less than $\frac{1}{400}$ to nearly $\frac{1}{100}$ inch in longest diameter.

From the facts and figures recorded in the foregoing petrographical determinations, many problems of more than passing importance to the student of applied geology may be profitably solved :—To wit, the examination of thin sections of stone under the microscope and its accessories, suffices to reveal not only the *quality* or true nature of their component parts, but their actual comparative proportions or *quantities* ; and, what is of more moment, the character of the association or relations of these to one another. Moreover, in the last example given above, of a consolidated blown-sand, it may be pointed out that the uniformly minute sizes of the clastic particles, serves to instantly indicate their æolian origin and to separate them from the closely allied consolidated shell-sands of sub-sedimentary or up-raised beach formation ; while their clastic constituents, by containing an appreciable proportion of fragments of lavas and their minerals,—such as augite and olivine,—furnish a clue to the proximity of volcanic rocks, which are nowhere in evidence along the adjacent coastal borderland; but may nevertheless be presumed to underlie only an inconsiderable thickness of Tertiary and Post-Tertiary strata, and perhaps to emerge at no great distance from the shore-line under the Arabian-sea. The practical up-shot of this deduction is, that the low-lying stretch of countryside which forms the southern moiety of the State, and which is periodically prone to suffer from drought, might be easily irrigated with a plentiful supply of potable water through the simple expedient of sinking artesian well-shafts into the zones of the closely underlying Deccan-Trap.

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INDEX TO THE QUARTERLY REPORTS.

Scientific and Vernacular Names are printed in *Italics*; Names of Persons in SMALL CAPITALS; Names of Places in **Thick Type** and Names of Subjects in Ordinary Type. All Numbers refer to Pages.

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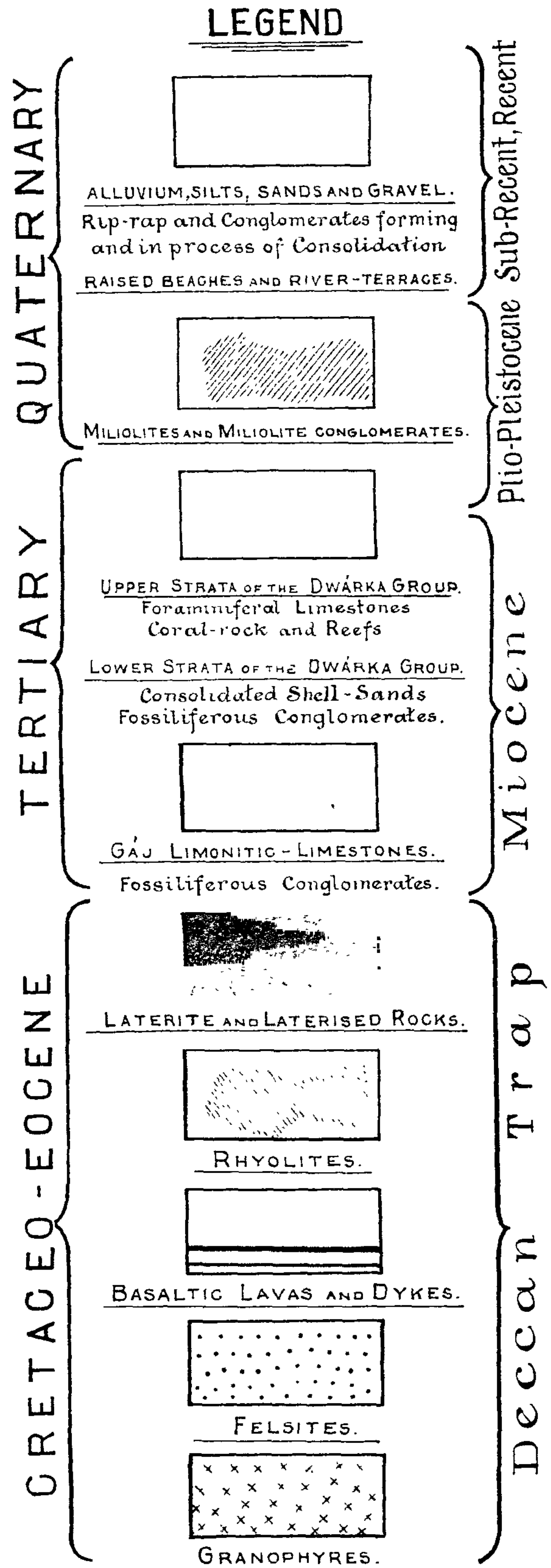
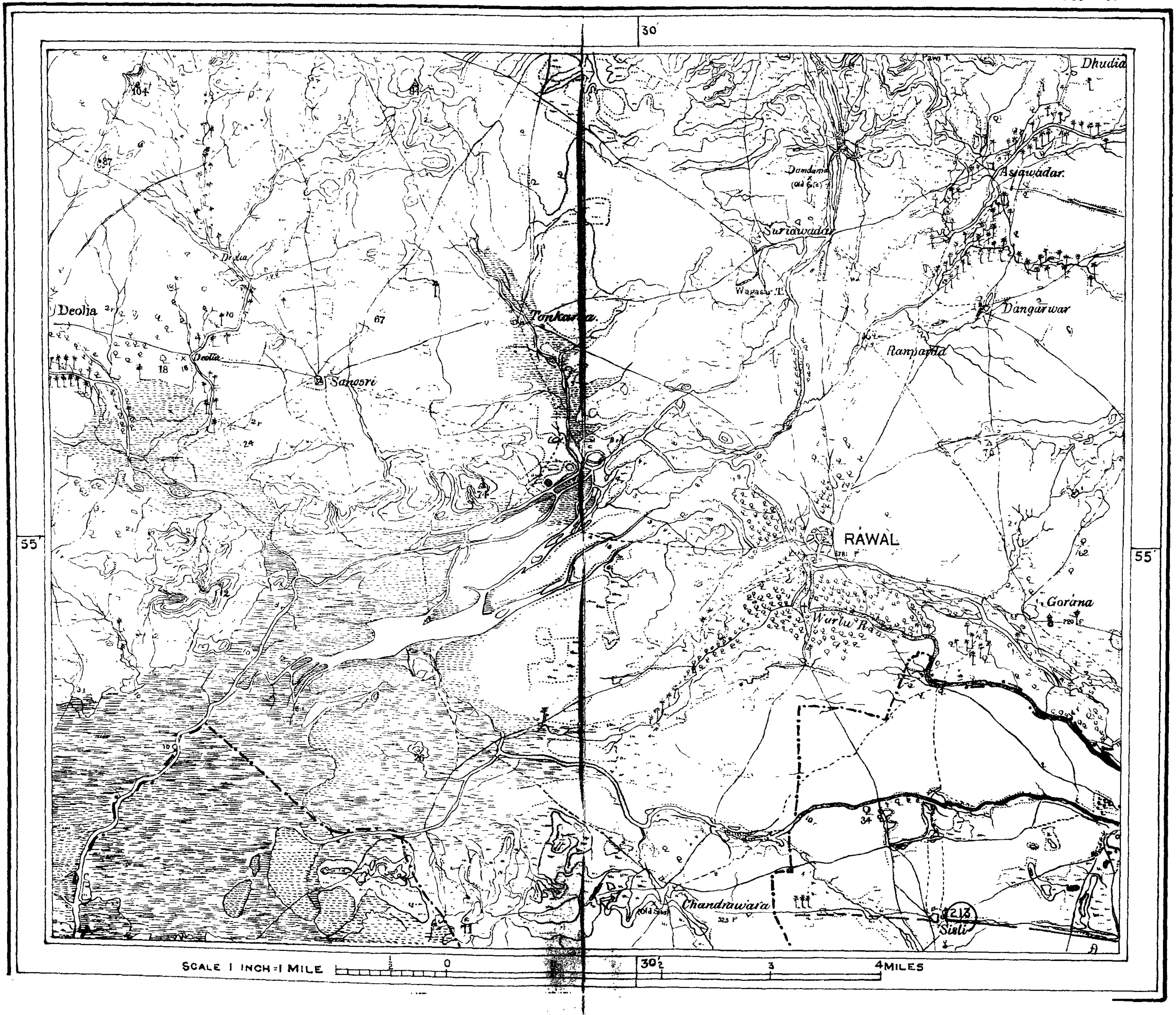
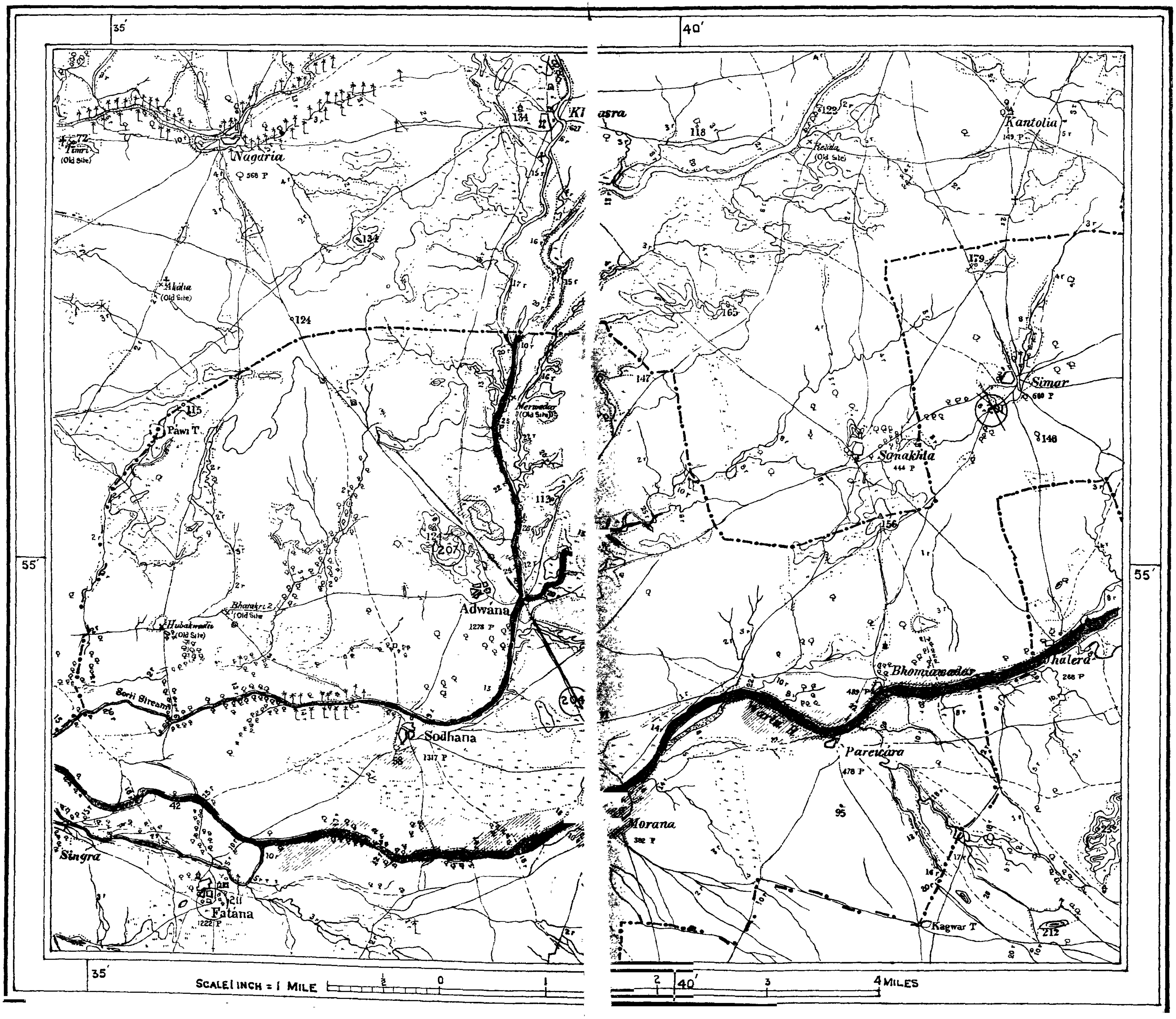
X

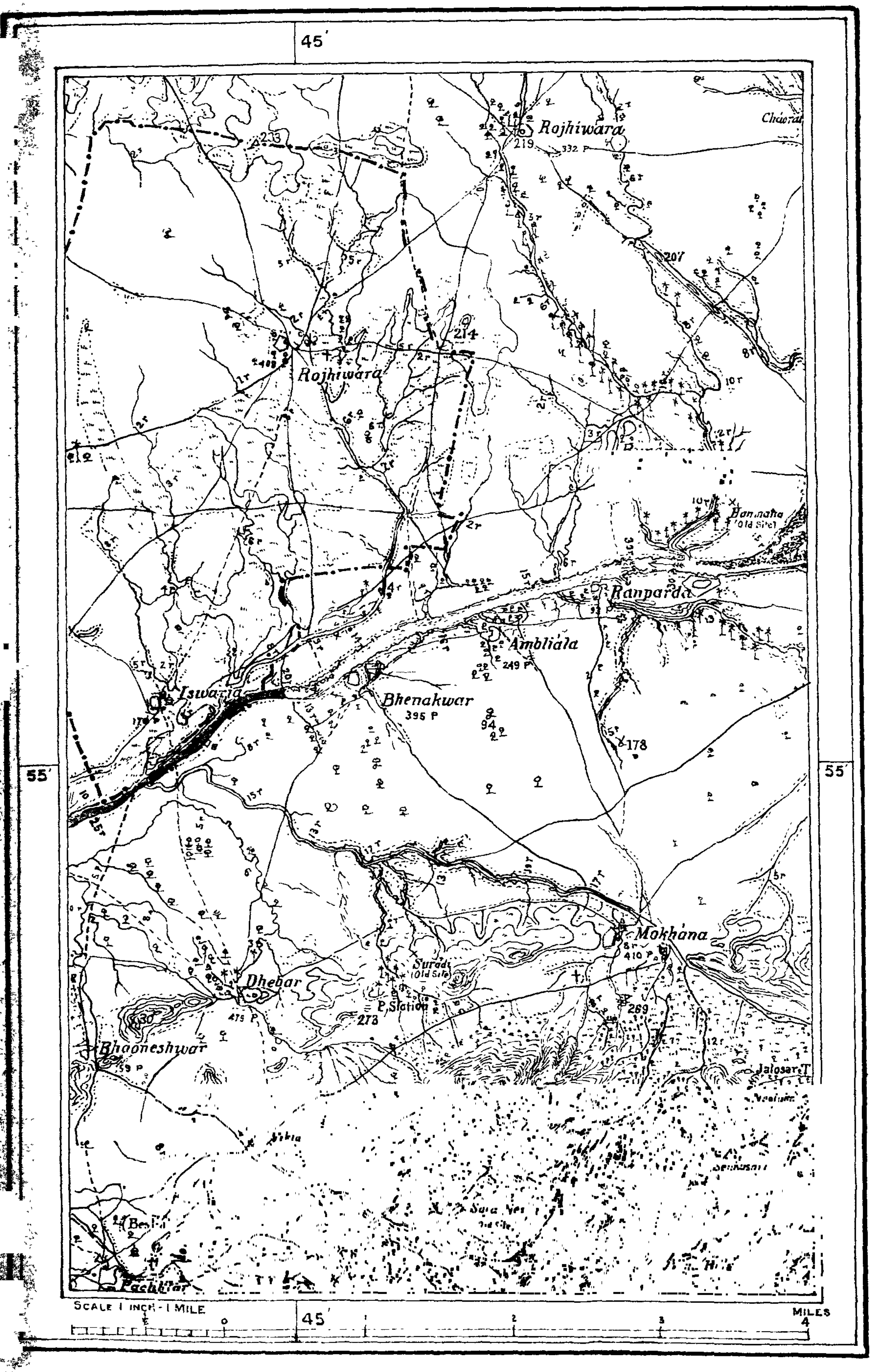

LEGEND
QUATERNARY
Sub-Recent, Recent
ALLUVIUM, SILTS, SANDS AND GRAVEL.
Rip-rap and Conglomerates forming and in process of Consolidation
RAISED BEACHES AND RIVER-TERRACES.
Plio-Pleistocene
MILIOLITES AND MILIOLITE CONGLOMERATES.
TERTIARY
Miocene
UPPER STRATA OF THE DWÁRKA GROUP.
Foraminiferal Limestones
Coral-rock and Reefs
LOWER STRATA OF THE DWÁRKA GROUP.
Consolidated Shell-Sands
Fossiliferous Conglomerates.
GÁJ LIMONITIC-LIMESTONES.
Fossiliferous Conglomerates.
CRETACEO-EOCENE
Deccan Trap
LATERITE AND LATERISED ROCKS.
RHYOLITES.
BASALTIC LAVAS AND DYKES.
FELSITES.
GRANOPHYRES.

MAP I.


30'
Dhudia
Dandama
(Old Site)
Suriawadar
Dangarwar
Deolia
Deolia
Sanosri
RAWAL
55'
55'
Gorana
Chandrawara
(Old Site)
Sisli
SCALE 1 INCH=1 MILE
4MILES

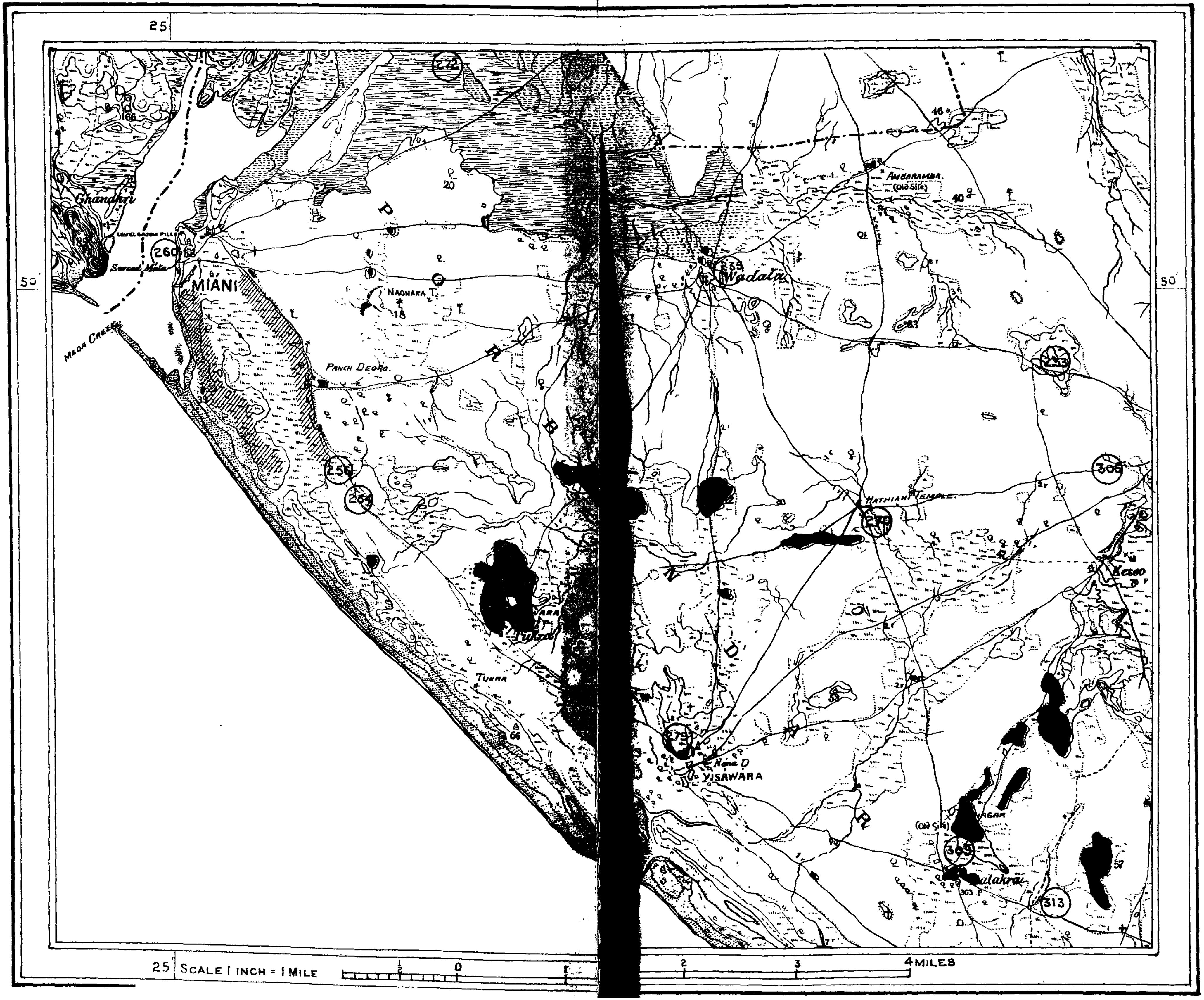

Nagaria
Timri (Old Site)
Kantolia
Simar
Adwana
Sodhana
Fatana
Singra
Morana
Parewara
Bhomiawadar
Dhalera
Sonakhila
Pawi T.
Kagwar T
Akalia (Old Site)
Hubakwadi (Old Site)
Bharakri 2 (Old Site)
Merwadar (Old Site)
Sorti Stream
Warta R.
35′
40′
55′
SCALE 1 INCH = 1 MILE
4 MILES

MAP 3.



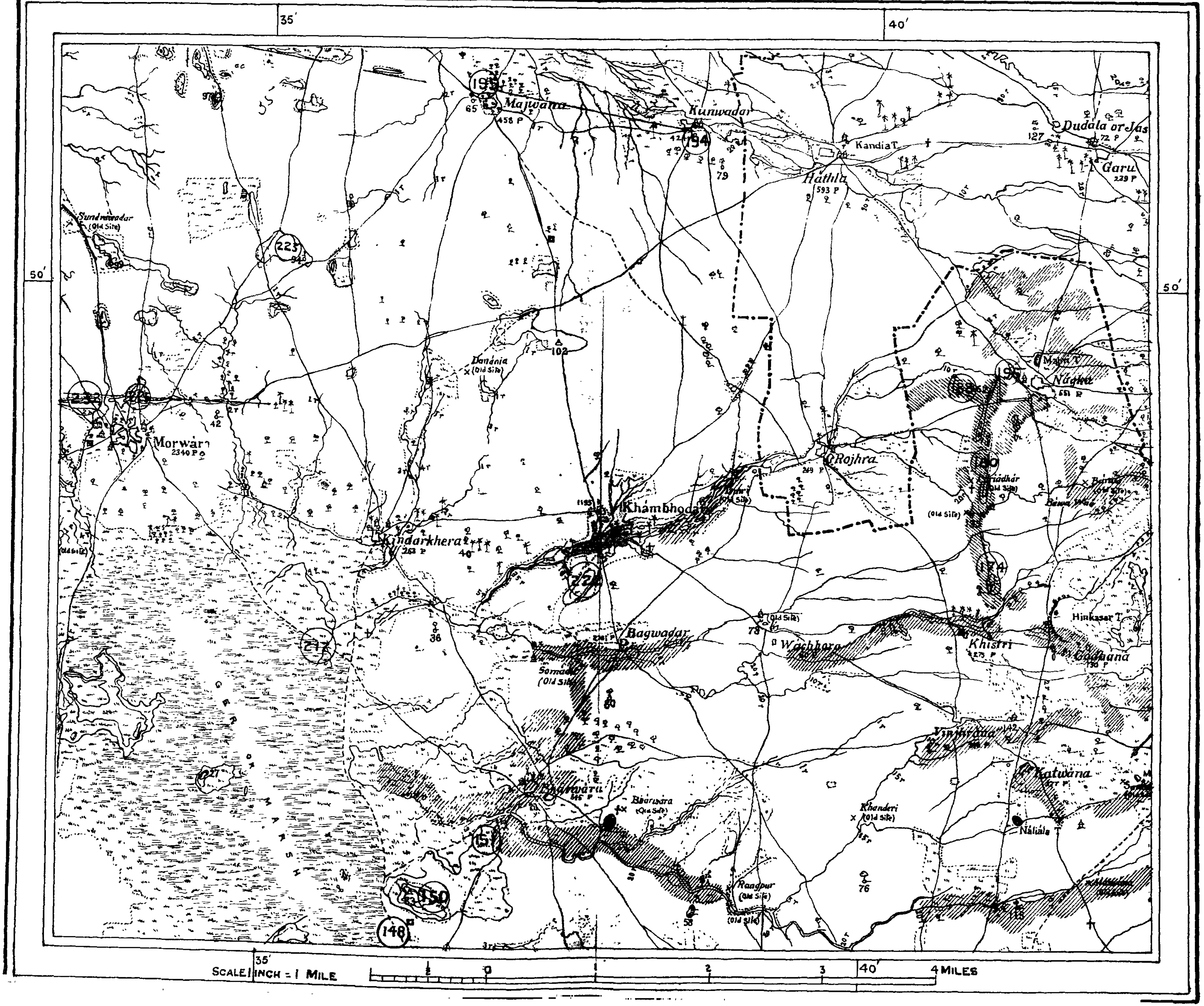
45'
Rojhiwara
219
332 P
Chaorai
233
207
214
Rojhiwara
Hanmaha (Old Site)
Ranparda
Ambliala
249 P
Iswaria
Bhenakwar
395 P
94
178
55'
55'
Mokhana
410 P
Suradi (Old Site)
P. Station
273
269
Dhebar
475 P
Bhaoneshwar
Jalosar T.
Pachhar
SCALE 1 INCH - 1 MILE
MILES
0
1
2
3
4
45'

MAP 4.

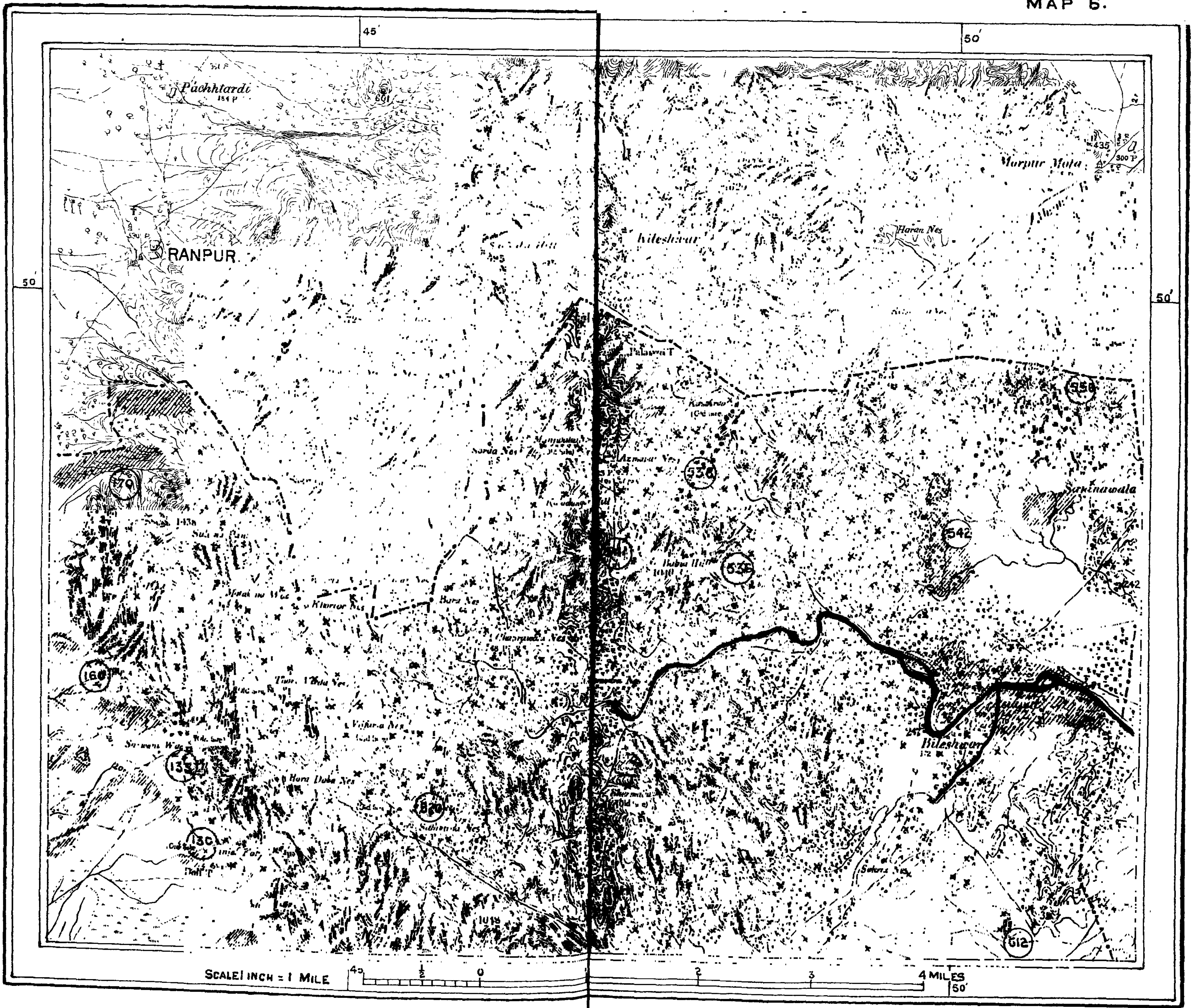


25
50'
MIANI
MEDA CREEK
PANCH DEORA
AMBARAMBA
(old Site)
Wadala
HATHIANI TEMPLE
Keseo
VISAWARA
TUKRA
(old Site)
SCALE 1 INCH = 1 MILE
4 MILES

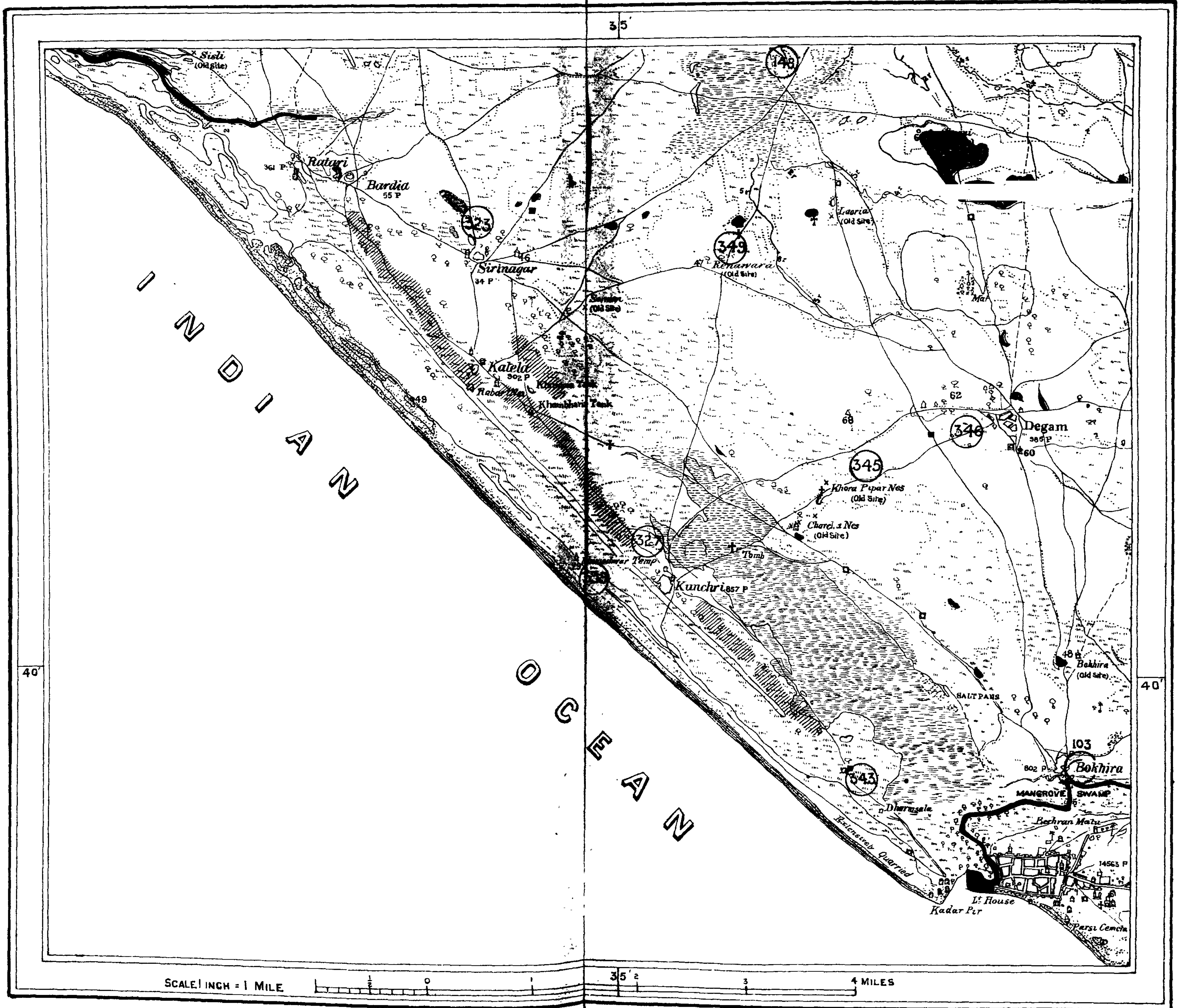
MAP 5.


35'
40'
50'
Majwana
Kunwadar
Kandia T.
Hathla
Dudala or Jas
Garu
Sundrawadar (Old Site)
Dandnia (Old Site)
Morwara
Nagka
Rojhra
Khambhodar
Kindarkhera
Bagwadar
Wachhoro
Khistri
Gadhana
Hinkaser T.
Somadi (Old Site)
Bharwara (Old Site)
Khanderi (Old Site)
Katwana
Naliala T.
Rangpur (Old Site)
SCALE 1 INCH = 1 MILE
4 MILES

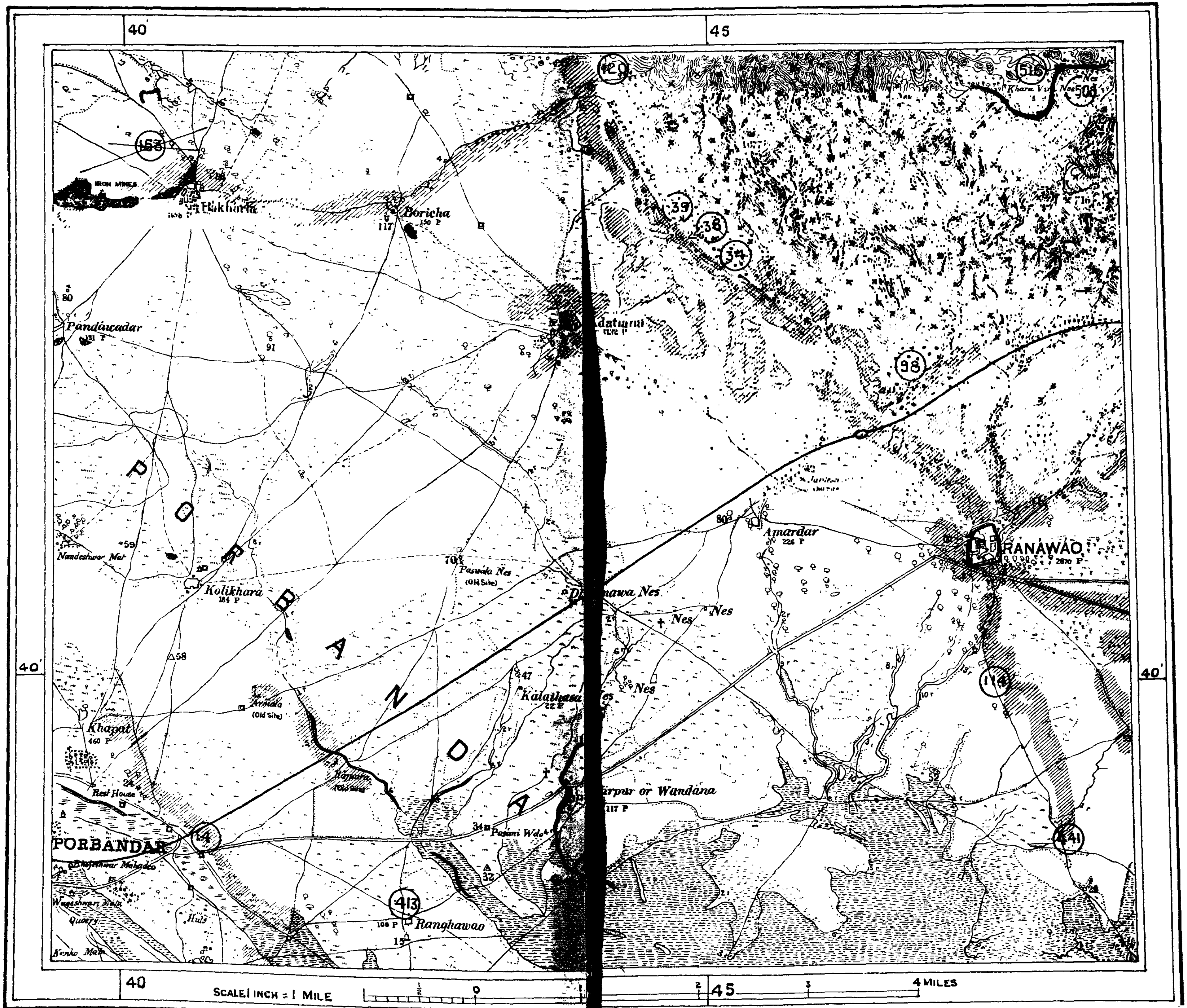
MAP 6.


45′
50′
Pachhtardi
RANPUR
Morpur Mota
Haran Nes
Bileshvar
Sanjnawala
SCALE 1 INCH = 1 MILE
4 MILES

MAP 7.

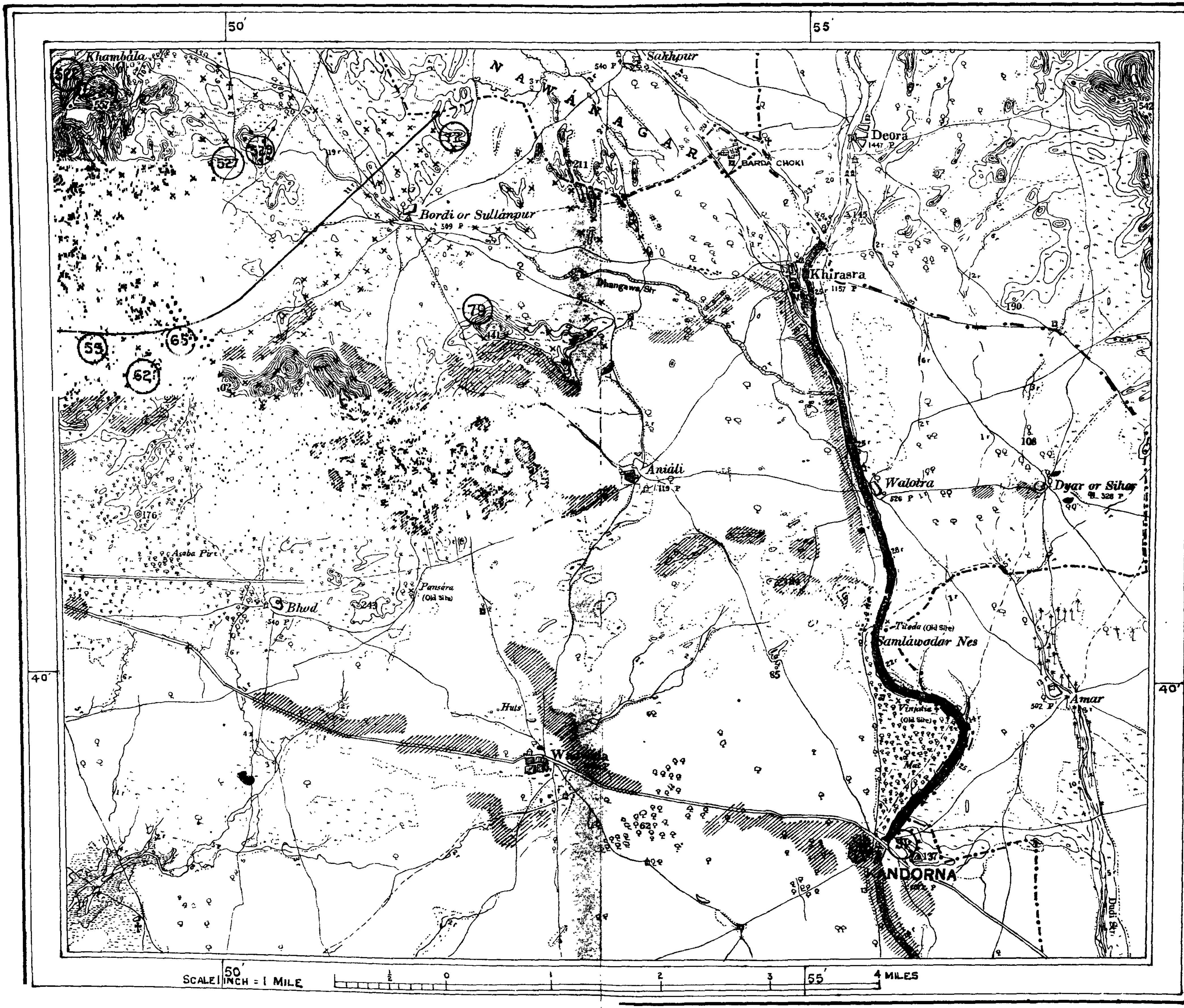

35′
Sisli
(Old Site)
Ratari
361 P.
Bardia
55 P
323
Sirinagar
34 P
Kateld
302 P
Khambhari Tank
149
349
Renavara
(Old Site)
Laoria
(Old Site)
Degam
385 P
346
345
62
68
60
Khora Pipar Nes
(Old Site)
Charel. i Nes
(Old Site)
Tomb
327
Kunchri 857 P
SALT PANS
Bokhira
(Old Site)
103
Bokhira
802 P
MANGROVE SWAMP
Bechran Matu
14563 P
343
Dharmsala
Extensively Quarried
Lt House
Kadar Pir
Parsi Cemetery
INDIAN OCEAN
40′
40′
SCALE 1 INCH = 1 MILE
1/2
0
1
2
3
4 MILES
35′

MAP 8.



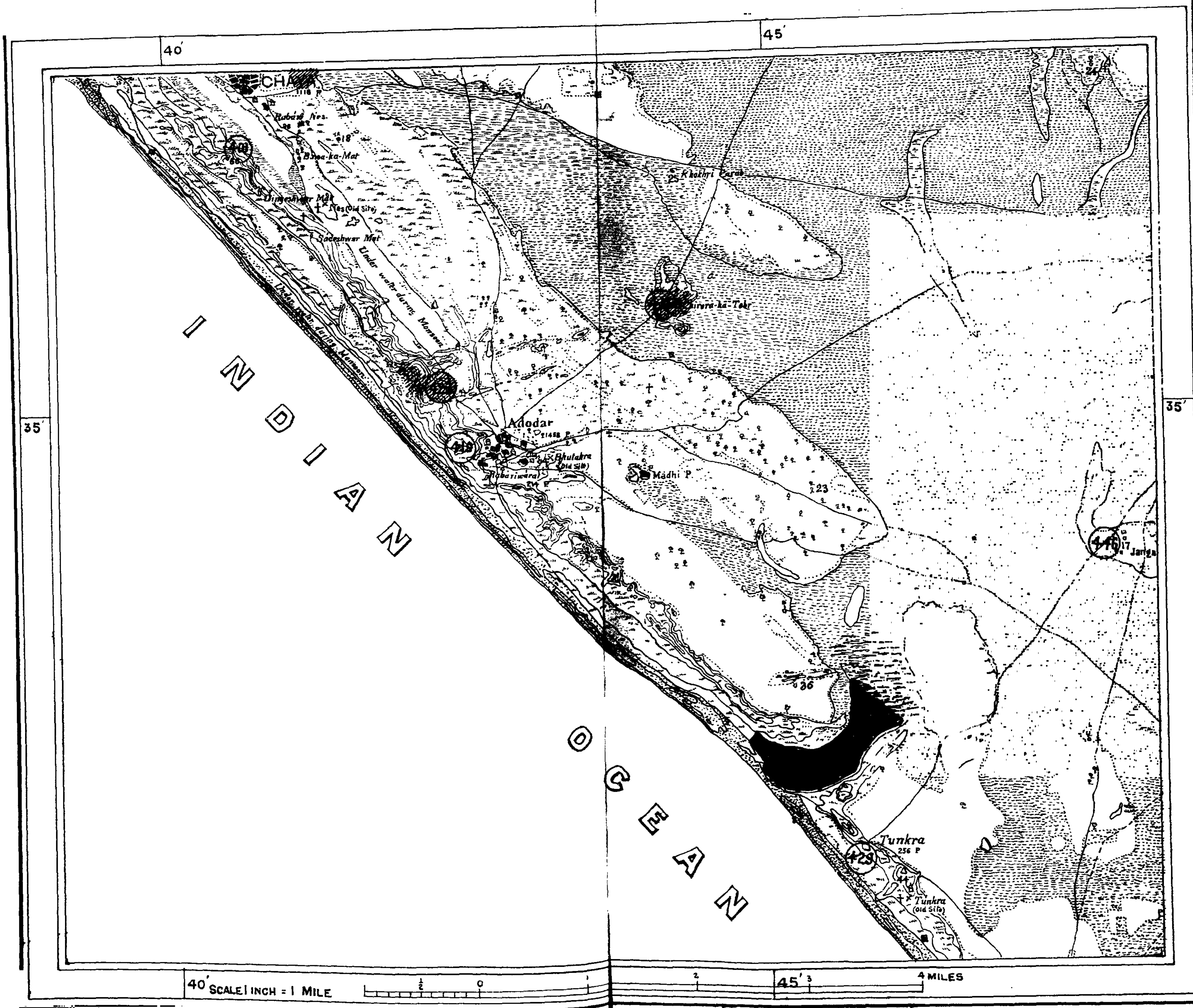
40'
45
40
45
40'
40'
IRON MINES
Bakharla
Boricha
Pandawadar
Adatiana
Amardar
RANAWAO
Kolikhara
Paswala Nes
(Old Site)
Nandeshwar Mat
Kalathasa Nes
Nes
Khapat
Rest House
PORBANDAR
Ranghawao
Pasani Wdo
Quarry
Kenko Mata
P O R B A N D A R
SCALE 1 INCH = 1 MILE
4 MILES

MAP 9.

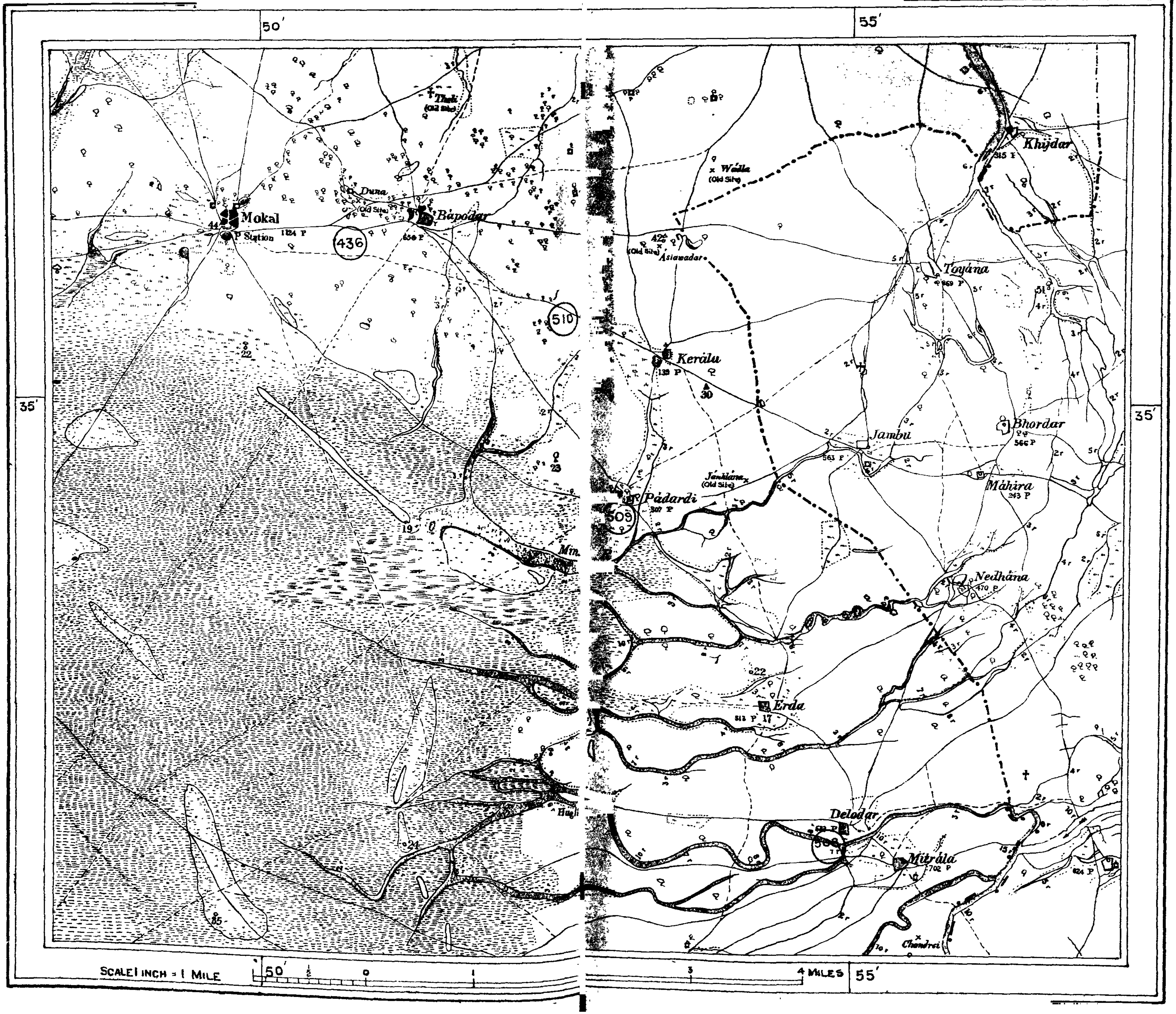


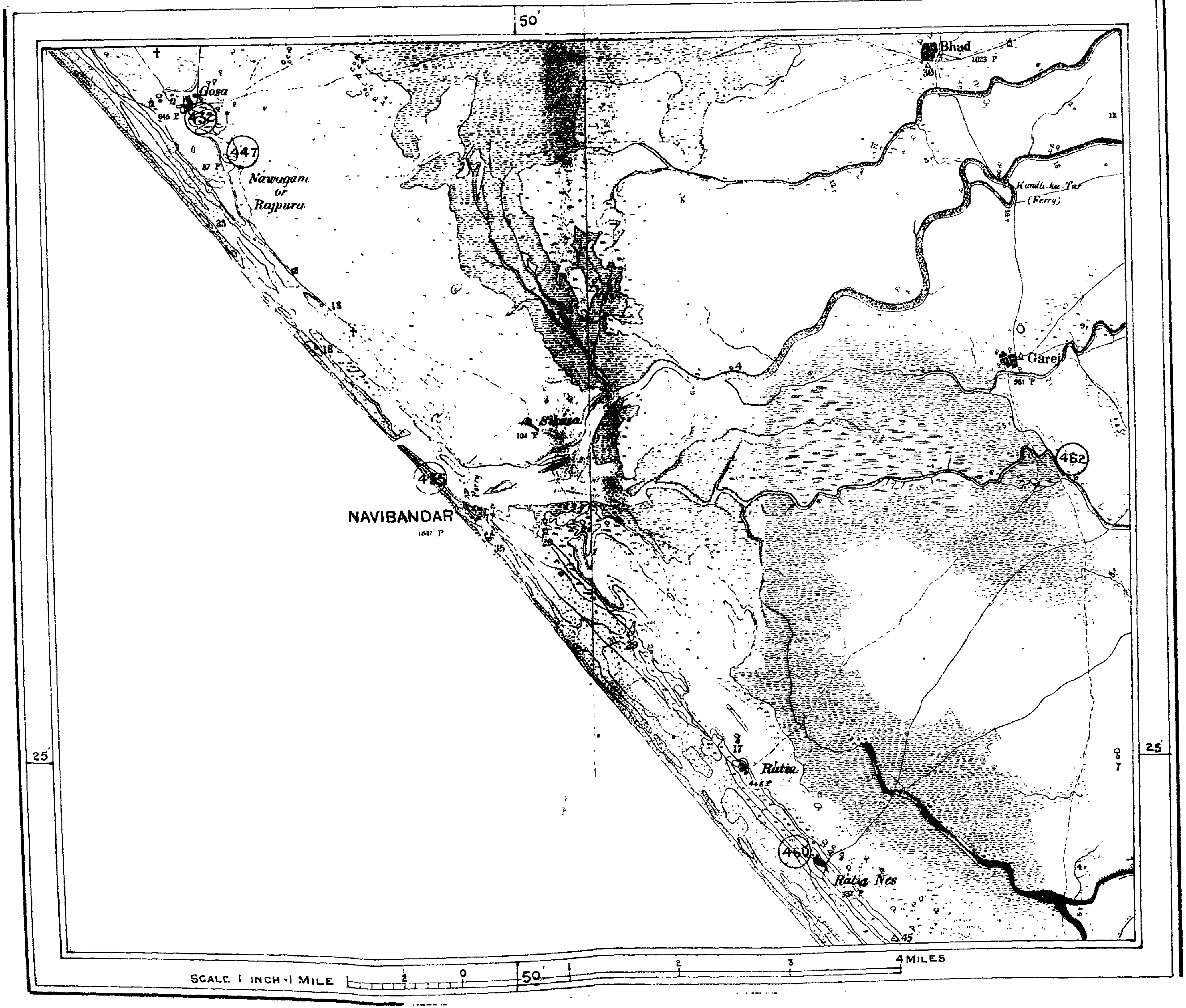
Khambála
Sakhpur
NAWÁNAGAR
Deora
BARDA CHOKI
Bordi or Sultánpur
Khirasra
Dhangawa Str
Aniáli
Walotra
Dyar or Sihar
Asaba Pir
Pansára
(Old Site)
Bhod
Tiloda (Old Site)
Samláwadar Nes
Amar
Huts
KANDORNA
Dudi Str
50'
55'
40'
SCALE 1 INCH = 1 MILE
4 MILES

MAP 10.



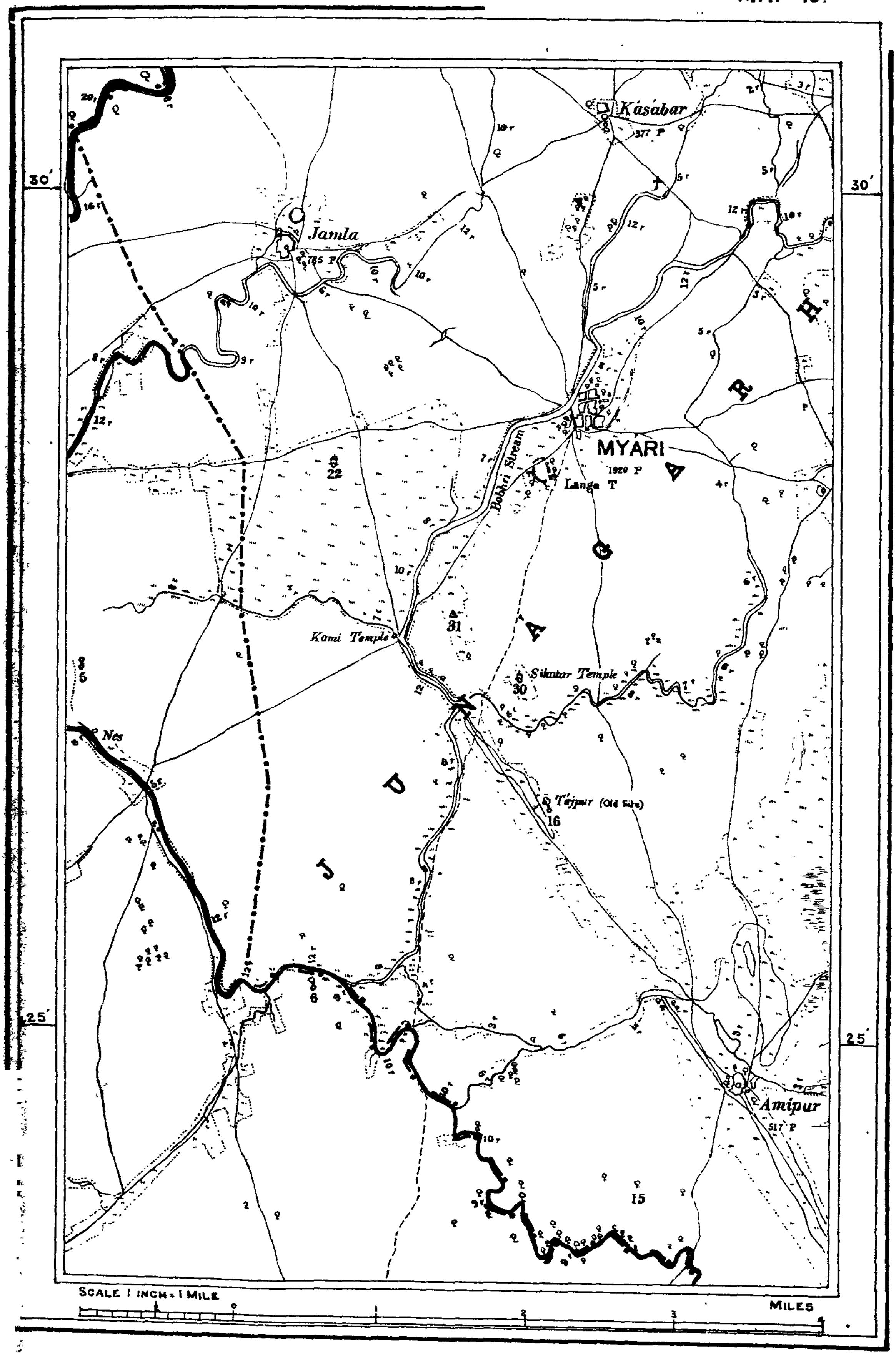
40'
45'
35'
35'
CHA
INDIAN OCEAN
Under water during Monsoon
Adodar
Bhutakra (Old Site)
Madhi P.
Tunkra
256 P
Tunkra (Old Site)
Janga
Khokhri Parab
23
36
40'
SCALE 1 INCH = 1 MILE
45'
4 MILES


50′
55′
35′
35′
Mokal
P Station
Duna
(Old Site)
Bapodar
Thali
(Old Site)
436
510
Khijdar
Walla
(Old Site)
Asiawadar
(Old Site)
Toyana
Keralu
Jambu
Bhordar
Mahira
Jankhana
(Old Site)
Padardi
509
Nedhana
Erda
Delodar
Mitrala
Chandrei
Hugli
SCALE 1 INCH = 1 MILE
50′
4 MILES
55′

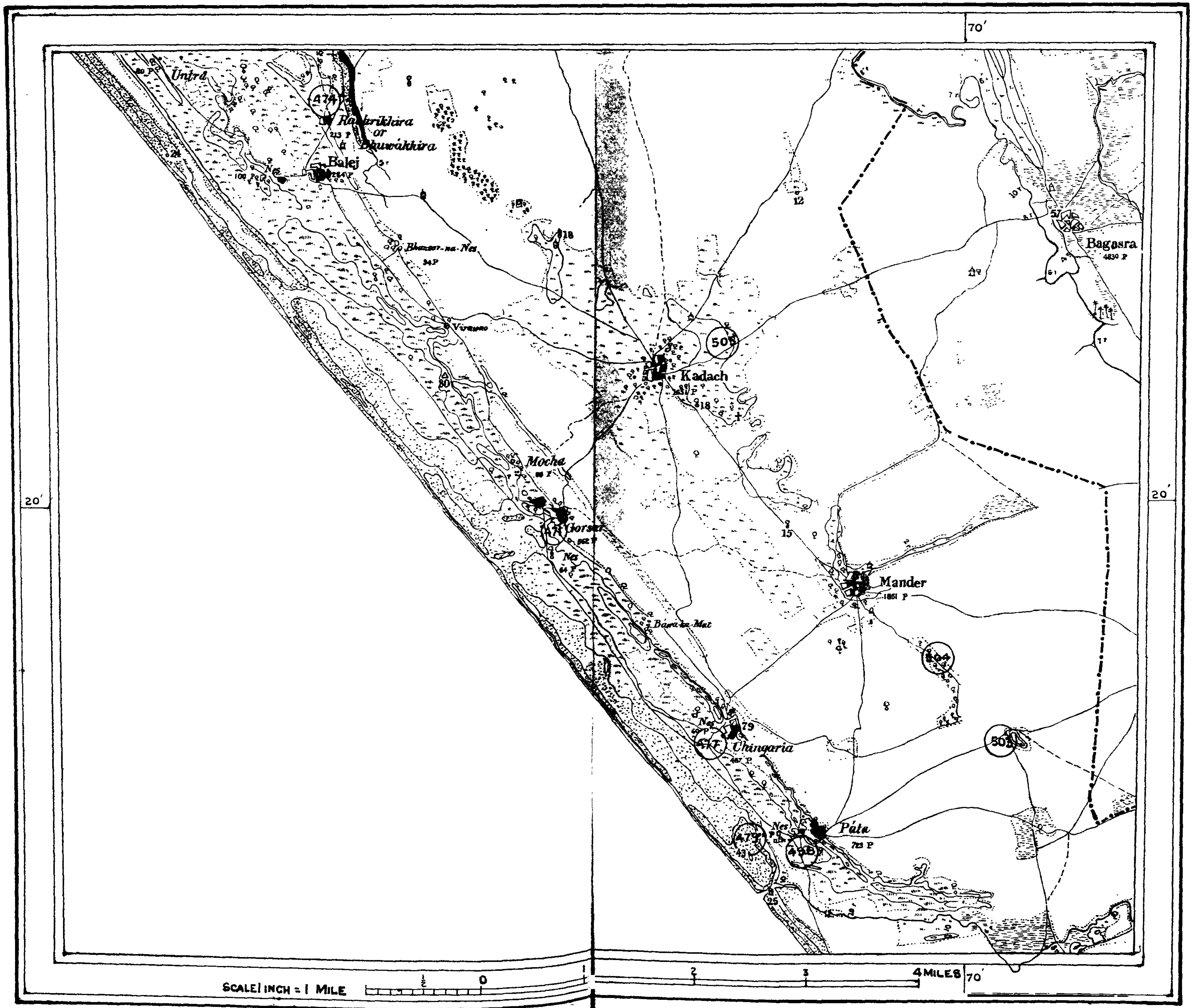


50'
Bhad
1023 P
Gosa
945 P
432
447
87 P
Nawagam or Rajpura
Kunili-ka-Tar (Ferry)
Garej
961 P
Sihasa
104 P
462
455
Ferry
NAVIBANDAR
1847 P
Ratia
446 P
460
Ratia Nes
25'
4 MILES
SCALE 1 INCH=1 MILE

MAP 13.

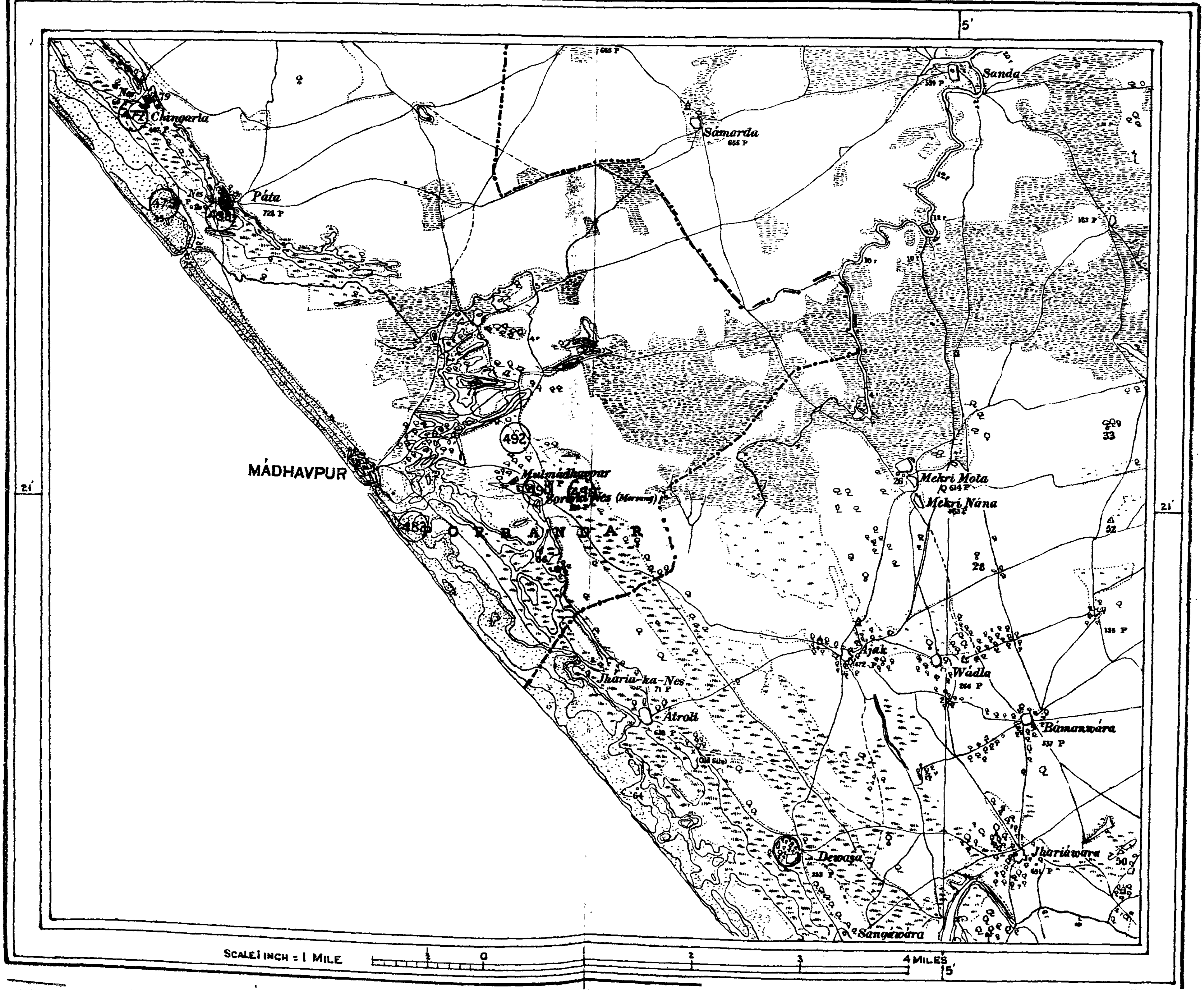


Kásabar
377 P
Jamla
785 P
MYARI
1920 P
Langa T
Bobhri Stream
Kami Temple
Sikantar Temple
Tejpur (Old Site)
Nes
Amipur
517 P
J U
A G
A R H
22
31
30
16
15
5
6
30′
25′
SCALE 1 INCH = 1 MILE
MILES
0
1
2
3
4



70′
20′
Balej
Mocha
Gorsar
Nes
Kadach
Mander
Bagasra
4830 P
1851 P
Chingaria
Pata
723 P
SCALE 1 INCH = 1 MILE
4 MILES

MAP 15.



Sanda
Sámarda
Chingaria
Páta
MÁDHAVPUR
Mulmádhavpur
Mekri Mota
Mekri Nána
PORBANDAR
Ajak
Wadla
Jharia-ka-Nes
Atroli
Bamanwára
Dewasa
Jhariáwara
Sangawára
492
21′
5′
SCALE 1 INCH = 1 MILE
4 MILES